VAN NOSTRAND'S
ECLECTIC
ENGINEERING MAGAZINE.

No. LXX.—OCTOBER, 1874.—Vol. XI.

# A PRACTICAL THEORY OF VOUSSOIR ARCHES.

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Written for Van Nostrand's Magazine.

1. The theory selected, in the following article, is that of Dr. Hermann Scheffler, * which will be quoted from literally in places. A sufficient number of experiments with wooden arches, probably to establish this theory, will also be given.

It is necessary to consider *the principle of the least resistance* in order that the thrust, anywhere in an arch, in direction, position and magnitude, may be located.

The Rev. Canon Mosely is the author of this principle, which has been amplified by Dr. Scheffler in his treatise above alluded to. It may be briefly stated thus:

*Principle of the least resistance.* Let the external forces which act upon a structure, be combined into one resultant, P; and let the resisting forces R′, R″ - - - be each decomposed into components respectively ⊥ and ∥ to the direction of P. Then will the components of R′, R″ - - - - ⊥ to P be the least that will cause equilibrium, consistently with the physical properties of the body or bodies composing the structure. *For* the sum of the components ∥ to P must equal P; but the components ⊥ to P are only brought into play from the peculiar disposition of the resisting surfaces of the structure and there is no need for their further increase after they have caused stability.

As M. Fournie observes: This supposes *first*, "that the *molecular* actions, which constitute the reactions, take place without sensible velocity;" *secondly*, "that the *molecular* actions are developed successively: so that the system cannot arrive at the position of greatest tensions without having passed through the positions of less tensions. Constructors willingly admit these propositions as plausible. The principle follows immediately."

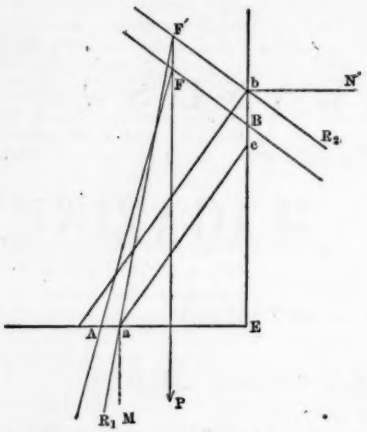
*Example.* * Let a beam, as in Fig. 1, lean against a horizontal wall at A and a vertical wall at B; its extremities may slide on those planes, requiring friction to prevent it. The weight P of the beam acts through its centre of gravity, and by the above principle, if the resultant resistances at A and B be decomposed into vertical and horizontal components: the sum of the vertical components = P and the horizontal components must be the smallest that the friction, between the walls and beam, will admit of: hence the directions of the resistances $F_1 R_2$ and $F_1 R_1$ must be as near the vertical as possible. But with regard to the physical disposition of the surfaces AE and BE, it

*Detailed in his most excellent German work, a French translation of which by M Victor Fournie is entitled "Traité de la Stabilité des constructions; 1re partie, Theorie des Voutes et des Murs de Soutènement." Paris, 1864.

* "Traité de la Stabilité," § 5.

is necessary to equilibrium that the directions of R and $R_1$ make angles with

FIG. 1.




the normals to BE and AE, at most, equal to the angles of friction $\phi_2$, $\phi_1$, of the ends of the beam on those planes: hence take $R_2$ $b$ N $= \phi_2$ which gives the direction of $R_2$. As the direction of $R_1$ must intersect that of $R_2$ on P: we have $F_1$ $R_1$ the direction of $R_1$.

It is evident that for incompressible voussoirs, the force $R_2$ passes through $b$ and $R_1$ through $a$, as this gives the least horizontal thrust; the directions of $R_1$ and $R_2$ being more nearly vertical than when they pass throug hany other points, as A and B.

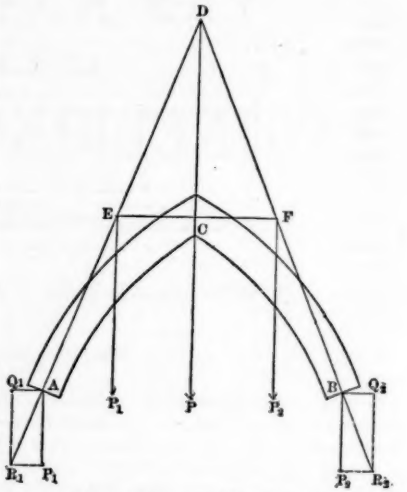
For an elastic, compressible beam; as it will bend as well as compress at the edges, the force $R_2$ will pass near edge $c$, and the force $R_1$ near edge $a$.

If by the construction above, $R_1$ $a$ M becomes $> \phi_1$ the beam will fall by sliding. The molecular resistances at A and B act along a portion of the surfaces $bc$, $a$A, for compressible beams, though they vary in intensity so that their resultants pass near the edges $c$ and $a$. For the mere supposititious case of an incompressible beam, the resultants pass through the edges, and hence there is but one molecular force acting on a mathematical point at either $b$ or $a$. An experimental proof of this theory will be given in Art. 10.

Most writers *assume* the force $R_2$ as horizontal, which is evidently only the case when there is no friction between the beam and the vertical wall. This is among the untrue hypotheses that are often so confidently stated by learned mathematicians.

SYMMETRICAL ARCHES.

FIG. 2.




2. * "We shall consider first an arch, formed of two branches AC, BC, (Fig. 2), symmetrical and placed in juxtaposition, and comprised between two parallel vertical planes $\perp$ to axis of arch," the arch being right cylindrical. "This arch, composed of voussoirs in the shape of wedges, formed of *incompressible* materials, leans against two abutments at its extremities A and B, and is loaded not only with its own weight but with any other weight whatsoever, distributed symmetrically on either side of the crown C. The mass of the arch is subject to the laws of friction in its joints. The adherence of the mortar, interposed between the voussoirs, being difficult to estimate will not be considered." As the two half arches are symmetrical as to the crown C, it is clear that the points of application, A and B of the reactions $R_1$ and $R_2$ of the surfaces of support, will be also symmetrical in relation to the vertical passing through the crown, and that the line AB will be horizontal, in whatsoever manner the points A and B may vary upon the surfaces of support.

* § 8.

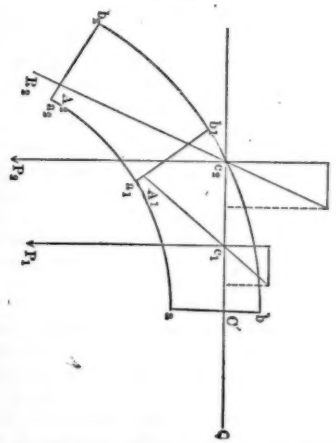
If we decompose the reactions, $R_1$ and $R_2$, into their horizontal and vertical components $P_1$, $Q_1$, $P_2$, $Q_2$, we should have $P_1 = P_2 =$ the weight of half arch with its load, and the thrust $Q_1 = Q_2$, should from the principle of the least resistance be a minimum.

Let us consider now one of the two halves, for example AC. Let $EP_1$ be the vertical passing through the centre of gravity of this half with its load; to hold this mass in equilibrium it is necessary that there exist at the crown a force whose direction CE passes through the point of intersection E of the vertical $EP_1$ with the direction of the reaction $R_1$.

As the vertical component of $R_1$ equals the weight $P_1$ acting through E, we conclude, without difficulty, that the tension at the crown C of the arch is necessarily equal to the second component $Q_1$, of the reaction $R_1$ and must be horizontal as it is.

From what precedes we are allowed to consider only a half-arch, leant against a fixed surface at A, and solicited by a horizontal force at C. When there is equilibrium, we shall seek the least value of this horizontal force Q and its point of application at the crown.

FIG. 3.




3. (Fig 3). Let $ab$, $a_1b_1$, $a_2b_2$, be the joints of an arch; $P_1$, $P_2$, the vertical directions of the weights of the parts $ab\ b_1a_1$; $abb_2\ a_2$; including the loads on the parts $bb_1$, $b_1b_2$, .... ; $P_1P_2$ acting through the centres of gravity of the parts considered. The horizontal force Q combined with the reaction $R_2$ at the joint $a_2b_2$ holds the part $abb_2a_2$ in equilibrium and similarly for the reactions on other joints.

At the points where the direction of Q cuts $P_1$, $P_2$, combine those forces with Q, the resultant of Q and $P_1$ cuts joints $a_1b_1$ at $A_1$, which is therefore the *centre of pressure* on that joint. As the weight $abb_2a_2$ with its load equals $P_2$ and is the weight on joints $a_2\ b_2$, the resultant of $P_2$ and Q will give the force acting on $a_2b_2$ in direction, position and magnitude; its direction cuts $a_2b_2$ at $A_2$, which is therefore the *centre of pressure* on that joint.

In the same way the resultants and centres of pressure on all the joints may be determined. A broken line connecting these *centres of pressure* on the various joints is called by Dr. Scheffler the *line of pressures*. For voussoirs indefinitely small it becomes a curved line.

That granted, in order that the arch may remain in equilibrium, it is necessary:

1. That the points of intersection C′, $A_1$, $A_2$, fall in the interior of the respective joints $ab$, $a_1b_1$, $a_2b_2$. If for any joint this is not so, *e.g.*, if the point $A_1$ was above $b_1$, the mass $abb_1\ a_1$ would then turn around the edge $b_1$, as an unresisted couple would be formed. To explain: suppose the resultant $R_1$ to pass outside of joint $a_1\ b_1$; conceive two equal opposed forces, each equal to $R_1$ to act at edge $b_1$; this does not disturb the equilibrium; then $R_1$ the force acting through $A_1$ (which is outside the joint) with its equal but not directly opposed force at $b_1$, would form the unresisted couple in question which causes overturning.

2. That the directions $c_1A_1$, $c_2A_2$ of the pressures upon the joints do not make angles, with the normals to the respective joints which exceed the angle of friction. If it was not so, sliding at the joints in question would occur of the mass above or below.

However, the friction of the materials usually employed in construction is sufficiently great to not give cause for fear as regards sliding, generally.

It is very easy to alter the direction of the joints should sliding be apprehended, hence it will not be considered further.

It is to be remarked that the foregoing theory does not require horizontal resistance in the spandrel, which is not generally built with the same care that is taken in the construction of the arch stones, and hence

cannot generally be regarded as unyielding; hence when a *line of pressures* such as $CA_1A_2$ passes, somewhere, out of the arch ring, a serious derangement of the arch may occur, even though the spandrel may prevent its falling: hence it appears to be a poor construction, to build such an arch, in preference to an arch in which the resultant pressures on the joints everywhere keep within the limits of the arch ring. This will be adverted to again.

4. It is necessary to demonstrate a few propositions, to locate the true line of pressures, corresponding to the minimum of the horizontal thrust.

The voussoirs will be considered indefinitely small; hence the line, drawn through the centres of pressure at each joint, will be a curved line, which is probably what it is in real arches, with voussoirs of any size. As before remarked, Dr. Scheffler calls this line, the *line of pressures.*

None of the joints will be supposed to make angles to the left of the vertical, looking upwards, greater than 90°

*(See Fig. 4.) If we vary at will the greatness and point of application of the horizontal force Q at the crown, we obtain curves which mutually cut each other. *But two such curves, which cut each other in any point whatsoever, D, will cut each other only at points situated upon the same horizontal as D; otherwise they will not meet again in any point above or below this horizontal.*

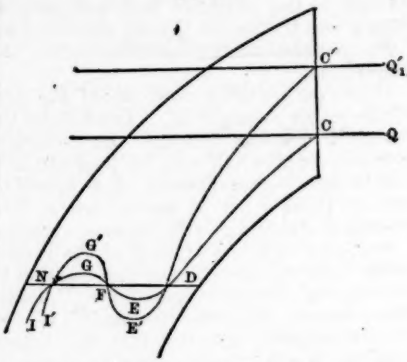
To demonstrate these propositions, let $P_1$ be the weight which corresponds to the *joint* that the curve of pressures traverses at the point D. Let $p_1$ = distance of the point D from the vertical through the centre of gravity of the weight $P_1$.

The moment of $P_1$ in relation to D is thus $P_1p_1$. If Q is the horizontal pressure at C and $z$ the depth of the point D below the horizontal through the point C, $zQ$ is the moment of Q as to D; D being a point of the curve of pressures.

We have the characteristic relation, $zQ=P_1p_1$. Let F be another point of the same curve at the *same height* as D. Let $P_2$, $p_2$, be the weight and lever arm, corresponding to the point F: $zQ=P_2p_2$ whence $P_1p_1=P_2p_2$.

If now a new curve of pressures is supposed to pass through D; $z_2Q_2=P_2p_2$ and consequently $z_1Q_1=P_2p_2$; hence it passes through F and cuts the first curve on the same horizontal as $D_1$.

FIG. 4.




Next let there be I, a point of the first curve which is not at the same height as the point D; $P_2$ the weight on the joint which passes through I; $p_2$ the distance from I to the vertical through the centre of gravity of this weight and $h$, the difference of level between I and D. We have for all curves, which pass through these two points.

$$z\,Q = p_1P_1 \text{ and } (h+z)\,Q = p_2P_2$$

whence

$$Q=\frac{p_2P_2-p_1P_1}{h} \text{ and } z=\frac{p_1P_1h}{p_2P_2-p_1P_1}$$

according to which, while $h$ has a finite value, Q and $z$ have necessarily *fixed values*, which can correspond but to a single curve of pressures.

Hence two different curves can never cut each other in two points situated at different heights. It may be remarked that isolated weights may produce curves of pressure like either of those drawn in Fig. 4, though such curves are but rarely met with in practice.

The meeting of two curves at C', E, G,—with a horizontal tangent is a contact and not an intersection; as we can consider the contact of the two curves as the coincidence of two points indefinitely near on the same level. For points, such as D, which have no horizontal tangent, the meeting is an intersection and not a contact from the same consideration.

In fact suppose for an instant that the dotted curve has contact only with the first at E. Suppose now the value of $Q_1$ to diminish from a change in the point of application of the thrust at the abutment.

*p. 34.

From a consideration of Fig. 3 we see that the curve will move down the joint, to the right of E, and hence must cut the first to the right of E and above it. Its other intersections, it has just been shown are at F, N - - at the same level as D, the first point of crossing.

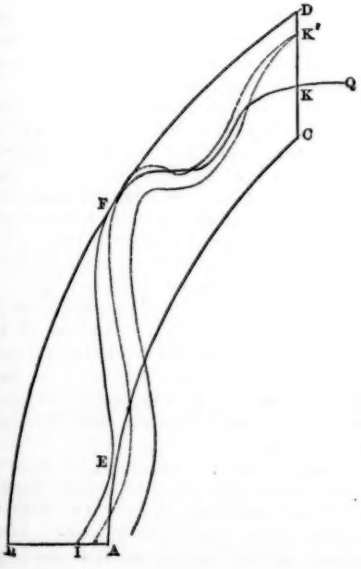
These important propositions being established, the problem before us is the following: Among all the curves of pressure, possible, which lie in the arch ring, find that for which the thrust Q is a minimum, and which by the principle of the least resistance is the only true one.

5. (See Fig. 5.) Proposition :—*When the point F, of contact with the extrados, is higher than the point of contact E, with the intrados, of a curve of pressures; it corresponds to the minimum of the thrust, whether the point E, precedes or follows the point F, going along the curve from the crown to the abutment.*

Fig. 5 represents the last mentioned case, which is the most usual; the other, being very rarely found in practice, will not be demonstrated. The case represented by Fig. 5 is demonstrated as follows:

1. If preserving the point of application K, we augment or diminish the thrust Q, the curve will either go outside of the extrados at F or the intrados at E, and hence will be impossible. This is easily seen from the construction of Fig. 3, where a greater horizontal thrust moves the points $A_1$, $A_2$ - - nearer the extrados, a less thrust toward the intrados.

FIG. 5.




2. If preserving the force Q, we raise its points of application towards D, we obtain a new curve, which is entirely above the first, which cuts then the extrados about the point F: it is then impossible. This may also readily be seen by a consideration of Fig. 3. If now we augment Q, the curve will be raised still higher near F and, of course, will go out of the arch ring and thus be less possible.

3. If, however, with the point of application still above K, at $K^1$ for example, we diminish Q so that the part of the curve near F may become tangent to the extrados, it is necessary that this new curve cuts the first K F E I *somewhere* between F and K. By Art. 4, as F is below K, this intersection may take place in a single point (lower dotted line), or according to the particular form of the curve in an odd number of points on the same horizontal (upper dotted line); so that, in all cases the new curve will be to the right of the first curve between F and the nearest point of intersection, but as below this last point the curve cannot meet again the first, it will remain constantly to the right of it; hence it will cut the intrados near E. It is then impossible. There cannot exist then a curve, under the assumed conditions, meeting the crown joint in a point higher than K.

4. If now we lower the point K without changing Q, the curve will cut the intrados above E, as it must remain below and to the right of the first curve; and for a stronger reason if Q is diminished. But if we increase the value of Q, in this new point of application below K, sufficiently, the curve may remain entirely in the interior of the arch, and generally an indefinite number of curves of pressure can be drawn in the arch. From what precedes, it follows that the curve K F E I, corresponds to the minimum of Q, since for the point K there is only one curve, for a point above K, there cannot exist a curve, and for a lower point, there are only curves corresponding to greater values of Q.

It will frequently happen that F coincides with D, and E with A; in which cases the meeting of the curves with the extrados or the intrados is not necessarily a con-

tact. The preceding demonstrations nevertheless hold.

6. When the point of contact F with the extrados is lower than the point E of the intrados, the curve of pressures corresponds to the maximum of the thrust Q.

It would be foreign to the purpose of this article to demonstrate this; (which is however easily done in the manner just shown; and in the same way the other case of the minimum is easily demonstrated) or to give all the cases where rupture occurs, which Dr. Scheffler has so fully illustrated.

Suffice it to say that the whole theory of curves of pressure is solved by him as simply as artistically. As he remarks: * "An exact knowledge of the actions that are produced in an arch can alone give to the constructor the proper confidence to design the form of an arch, the thickness of the arch, the joints, and the abutments in such a manner as to assure the stability of all the parts; and this is especially true of a new work, where experience and analogy do not furnish the needed information."

Numerous experiments will be given in the sequel, which will be found to agree with this theory, and to establish it practically, taking into consideration the compressibility of the materials used.

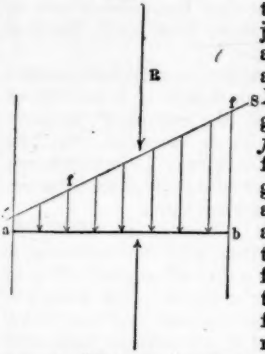
7. Before going further, it would be as well, perhaps, to make some remarks about the effects produced by the compressibility of the voussoirs and mortar. As the law of that compressibility is unknown, we can not tell exactly how far from the edges of the joints is the nearest approach of the curve of pressures in an arch. It may be kept in view though that the resultant pressure on any joint, can be exactly at the edge of the joint only for *incompressible voussoirs* that can receive a finite effort upon a mathematical line. For actual bodies, this finite force must be distributed over a finite surface.

Let the molecular reactions, which make up the resultant on each joint, be supposed parallel in direction. Conceive a plane passing through the resultant R (Fig. 6) on any joint, parallel to the intrados at the joint in question.

Call an *elementary resisting force* on one side of this plane $f$, and its lever arm in relation to that plane $l$. Likewise call $f'$ and $l'$ an elementary force, and its lever arm on the other side of this plane; then we must always have

$$\Sigma f l = \Sigma f' l'$$

FIG. 6.




It is evident that if at any joint the resultant passes near an edge b, that $\Sigma f$ is much greater than $\Sigma f'$, as the last forces act with greater lever arms; hence in any actual arch the resultant falls back a certain distance from the edge necessarily on account of the greater compression produced at that edge; and this is moreover necessary to prevent crushing, as our materials are not infinitely strong.

For example, in the head of the bridge of Neuilly, the horizontal thrust at the crown on a slice 1ft. in thickness is about 109 tons, supposing the line of pressures to pass through the upper edge of crown joint. In reality it is at a certain distance from this edge, which if we knew as well as $\Sigma f$ between that distance and the edge, we could form a better idea as to whether the surface included was able to bear the thrust. Thus suppose in this case that $\Sigma f = \frac{3}{4}\ 109 = 82$ tons and on such a small surface as we shall find that it is uniformly distributed. If the crushing force of the stone is taken at five tons per sq. in, this would require a bearing surface of $82 \div 5 = 16$ sq. in.; *i.e.* the resultant could pass within 1.33 inches of the edge without causing rupture. Mortar has a much less crushing weight than good granite in blocks, but for a mortar joint only say $\frac{1}{8}$ inch thick, its crushing weight must approach that of some building stones, and probably the resultant could pass within 6 inches of the edge in this bridge without causing rupture. There are reported many cracks in the head of this bridge. It is very probable though that the resultant retreats farther in the arch ring, for swift rolling loads could then too readily crush the edges, as the molecular resistances take time to act and assume their final magnitude, the curve of pressure changing with every rolling load. Again, take the viaduct Fig. 9, which is 50ft. span

* p. 193.

and 10ft. rise; the horizontal thrust on 1ft of thickness is 20 tons, which can be borne on a surface of 4 sq. in. by granite, the mortar requiring the line of pressures to retreat a few inches from the edge. The depth of the voussoirs at the crown in this bridge is 2.5ft.; for the bridge of Neuilly 5.3 feet; we thus see that the resultant *may* pass, proportionally to the depth of the voussoirs, very near the edge without causing crushing, and as on most bridges there is no crushing at the edges, we infer that this resultant must pass a certain distance from the edge in every instance.

The mortar may, besides giving a more intimate, and consequently a greater bearing surface, cause the line of pressures to retreat within the arch ring, thus distributing the thrust a little more uniformly over the joint. Suppose the centre of an arch struck as soon as it is turned, while the mortar is still fresh at the crown; for the usual forms of bridge arches, the mortar will be compressed, and in fact squeezed partially out at the upper edges of the joints near the crown, and this will be the more marked the thicker the joints.

However, as the mortar hardens during the building of the spandrels, the line of pressure will afterwards approach the top of the crown joint as the arch is weighted down, any sinking of the crown being attended with a more intimate contact at the upper bearing surfaces at the crown. This becomes still more evident when we suppose a rolling load on the crown of an arch whose mortar joints have completely set, and likewise consider that the abutments yield slightly.

Shaving off the upper parts of the joints near the crown would tend to counteract this.

Dr. Scheffler thinks that, for good stone, if we can draw a line of pressures, within the arch, that nowhere approaches nearer the edges than $\frac{1}{4}$ depth of joint, that the stability of the arch is assured.

Dr. W. J. M. Rankine gives $\frac{1}{3}$ depth of joint as the nearest approach to the contour curves.

The experiments that will be given show very plainly that the total thrust on a joint, together with its special compressibility, alone locates the true curve of pressures, so that it will depend principally upon the dimensions of the arch and surcharge; for a small arch being very near the edges at the joints of rupture, for a larger arch with a greater thrust, at a greater distance from these edges.

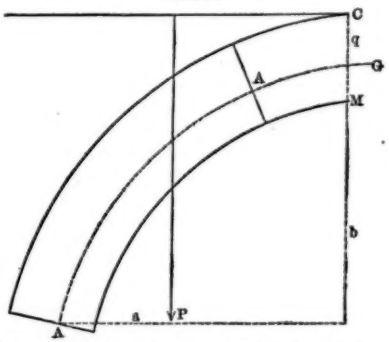
It is a fact, in some existing arches, that the voussoirs at certain points are pressed together near their edges, the joints slightly opening on the other side.

At any rate wherever the engineer locates these circumscribing, limiting curves, to the curve of pressures, the latter must always conform to the minimum of the thrust in the limits chosen.

If no curve of pressure can be drawn in the limits, the depth of the voussoirs must be increased on part or the whole of the arch; or the profile may be altered; or finally we may combine both of these methods to secure stability.

8. Let us consider as in Art. 2 a slice of the arch 1 unit thick. In Fig. 7, let Q= the horizontal thrust (compare Fig. 3 throughout); $q$, its vertical distance below the apex C; P=weight of an arch and load

FIG. 7.




C A on joint at A; $a$=horizontal distance from A, the centre of pressure on the joint, to the vertical passing through the centre of gravity, P; $h$=vertical distance between C and A; $b$=vertical distance between M, the point of application of Q at the crown, and A.

If we consider another point A′ of the curve of pressures, at a vertical distance above A=$e$, we shall have an analogous notation $P_1$, $a_1$, $b_1$.

If we know the points M and A, we have

$$a\,P = b\,Q \quad \therefore Q = \frac{a\,P}{b} \quad \ldots\ldots\ldots (1).$$

If we know any two points as A, A′, $a\,P = b\,Q = (b' + e)\,Q$; also $a'\,P' = b'Q'$ hence

$$Q = \frac{a\,P - a'\,P'}{e} \quad \ldots\ldots\ldots (2)$$

$$q = h - \frac{a\,P}{Q} \quad \ldots\ldots\ldots (3)$$

Having obtained from eq. (1) or eqs. (2) and (3), Q and its point of application at the crown, we find where the resultant pressures cut each joint as in Art 3, and if these points are within the proper limits of the arch ring and satisfy the minimum of the thrust, the curve is the true one. From eq. (1) it is evident that Q is smaller as $b$ is greater or $a$ smaller; hence the true curve will pass as near C, and the lowest point of the joint at A as the compressibility of the material will admit of.

If the first curve drawn, passes outside of the prescribed limits in one or more places; take points on the limiting curves opposite the points of maximum departure, and by eqs. (2) and (3), pass a curve through two of these points.

If the arch is stable at all, it will almost invariably be found in practice, that the last curve so drawn will fulfill the required conditions of remaining in the prescribed limits and corresponding to the minimum of the thrust. If not a third approximation may be tried, and so on.

In all the numerous and varied examples that Dr. Scheffler works out, he never resorts to a third trial; and in practice, after becoming familiar with the leading cases, the first trial is generally sufficient, when the limiting curves are assumed, as the writer can testify to from experience. Thus this theory does not demand an unlimited number of gropings as Poucelit asserts,* so as to render the method nearly illusory in practice.

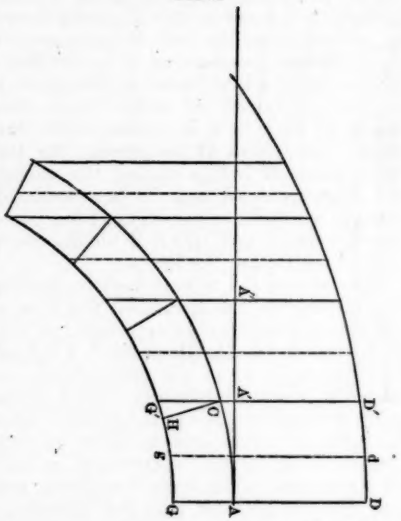
Let us now proceed to show how to find the centres of gravity of the weights $abb_1a_1$, $abb_2a_2$, (Fig. 3), as also the magnitudes of those weights. If the arch is loaded with any weights, reduce them to the same specific gravity as that of the masonry of the bridge supposed homogeneous, as follows: Lay down these weights in their exact positions on the arch and alter the vertical dimensions to conform to the specific gravity of the stone. We shall thus substitute blocks of stones, by scale, for the surcharge of earth, water, etc., or the rolling load.

By this means we have the solid contents of $abb_1a_1$, etc., proportionate to the weights $P_1$, $P_2$ - - - and hence can be taken for them.

We now divide the horizontal through A (Fig 8) into an appropriate number of parts and through these points of division, draw verticals from the intrados to the curve DE that limits above the load.

Regard each trapezoid DGG'D' as a rectangle, and calculate its surface by multiplying its horizontal width AA' by the mean vertical $dg$. Next regarding the centre of gravity of each trapezoid as that of the corresponding rectangle, we shall find the centre of gravity of the trapezoid DD'G'G, for example, to be upon the mean vertical $dg$. which equally divides the horizontal AA'. Draw through C, the

Fig. 8.




joint CH; the weight DD'G'G will be considered as resting on the joint CH; which is in excess by the small triangle CG'H, an error too small to be regarded in flat arches.

There is, however, given by Dr. Scheffler, a very simple construction for a closer approximation to the truth. Further on will be indicated another method, which gives all desirable accuracy for any form of arch. In fact, considering that in practice arches are neither homogeneous nor symmetrical, perfect accuracy is not necessary, as there should be a margin left to allow for these variations always. In the case of the experiments with the wooden voussoirs, the writer has used a method which leaves nothing to be desired on the score of simplicity and accuracy.

Now if we multiply the surface of each

*Scheffler, p. 222,

trapezoid by the horizontal distance of its centre of gravity from A; the sum of these moments divided by the sum of the trapezoid surfaces (which are also the volumes), will give the horizontal distance from A to the centre of gravity of the whole part considered. This method will thus give us the weights $P_1$ $P_2$ - - - (Fig. 3), as well as the horizontal distance of their centres of gravity from the crown.

*First Example.*—Let us illustrate by an

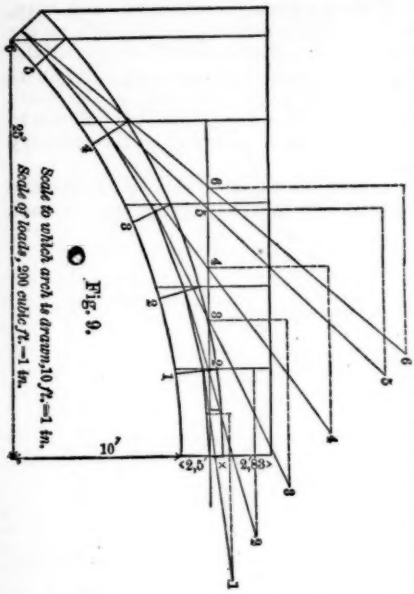



Fig. 9.

example of a railroad bridge (Fig. 9) of 50 ft. span and 10 ft. rise, the arch being a segment of a circle; voussoirs 2.5 deep; the spandrel walls rising 2.83 ft. above the summit of the arch ring. The arch is 7 ft. thick, but we shall consider but a vertical slice of it 1 ft. thick.

In the following table, the first column gives the number of the joint from the crown; the second (w) the width of the horizontal divisions AA', A'A''- - of Fig. 8; the third (v) the corresponding mean heights *dg* - - -; the fourth (s), the product of these dimensions, giving thus the surface of each trapezoid. Column (c) gives the distances of the centre of gravity of each trapezoid from the crown; column (m) the product of (s) and (c). Now we cumulate, giving from the crown in the next two columns these surfaces and products (s + c); column (S) being formed by adding the surface of each trapezoid to the total surface, just found, which precedes it. The last quantity in column (S) should = sum of column (s).

In the same way, column (M) contains the continued sum of column (m), and hence its last number should equal the sum of column (m). Dividing now the numbers in column (M) by the corresponding ones in column (S) we get, column (c), the horizontal distances of the centre of gravity of each weight $P_1$, $P_2$ — — corresponding to joists 1, 2 - - - from the crown.

TABLE 1.

| | w | v | s | c | m | S | M | C |
|---|---|---|---|---|---|---|---|---|
| 1 | 5 | 5.4 | 27. | 2.5 | 67.50 | 27. | 67.50 | 2.5 |
| 2 | 5 | 6.1 | 30.5 | 7.5 | 228.75 | 57.5 | 296.25 | 5.1 |
| 3 | 5 | 7.6 | 38. | 12.5 | 475. | 95.5 | 771.25 | 8.1 |
| 4 | 5 | 9.8 | 49. | 17.5 | 857.50 | 144.5 | 1628.75 | 11.3 |
| 5 | 5 | 13.2 | 66. | 22.5 | 1485. | 210.5 | 3113.75 | 14.7 |
| 6 | 1.75 | 14.5 | 25.4 | 25.9 | 657.86 | 235.9 | 3771.61 | 16. |
| | | | 235.9 | | 3771.61 | | | |

The preceding table shows that the *surface* (or *content*, for a slice 1 ft. thick) of the half arch with its load equals 235.9 sq. ft.; its moment as to the crown is 3771.61 and the distance of its centre of gravity from the joint at the crown is 16 ft. Hence (see Fig. 7,) we have to pass a curve of pressures, through the crown joint, $\frac{1}{3}$ of its depth from the summit of the arch and through joint 6 at $\frac{1}{3}$ of its depth above its lowest point, if we decide on account of shocks due to passing loads, imperfection of workmanship, etc., to require that the curve of pressures shall not pass outside of the middle third of the arch ring. By measurement on the drawing (Fig. 9) we find a=25.6—16=9.6, $b$ = 11.2. We have also P=235.9 cubic feet of stone; hence by formula (1)

$$Q = \frac{a\,P}{b} = \frac{235.9 \times 9.6}{11.2} = 202 \text{ cubic ft. stone}$$

which may be reduced to tons, when desired, by multiplying by the weight in tons of a cubic foot of stone.

If now at the points of intersection of the horizontal through the point of application of Q at the crown, with the verticals passing through the centres of gravity of the surfaces given in column (S), ($P_1$ $P_2$- - - of Fig. 3), the points of intersection, of the resultants of Q with these weights $P_1$, $P_2$, . . . with the corresponding joints, will be points in the curve of pressures sought.

For example, to determine where the line of pressures cuts joint 4, lay off the distance in column (C), 11.3 horizontally from the crown, then on a vertical lay off upward from this point the corresponding weight on joint 4, given in column (S) 144.5; drawing a horizontal line, through the last point found=Q, we get the resultant by completing the triangle of forces.

Producing this resultant to intersection with joint 4, will give the centre of pressure on that joint. It will be advisable, in practice, to prick off the centres of gravity, taken from column (C), at one operation and number each one with the number of the corresponding joint to avoid mistake.

On continuing this construction for each joint, we shall find that the line of pressures remains within the inner third of the arch ring.

It may be remarked that the small triangle mentioned is in excess only for the joint in question; thus this error is not carried on. The ordinary method of constructing a line of pressures is to combine any resultant with the next weight following, regarded as concentrated at its centre of gravity.

By this construction any small error in draughting is carried on, whereas, by Dr. Scheffler's method, it is confined only to the joint where it occurs first.

With accurate instruments and care, using a sufficiently large scale, this method of Dr. Scheffler's should answer all the requirements of accuracy, and will generally be found the shortest in the end; whereas, with many joints, it is difficult to locate this curve precisely by the ordinary method.

*Second Example.*—(Fig. 10.) Suppose a load of two 40-ton engines, one on each

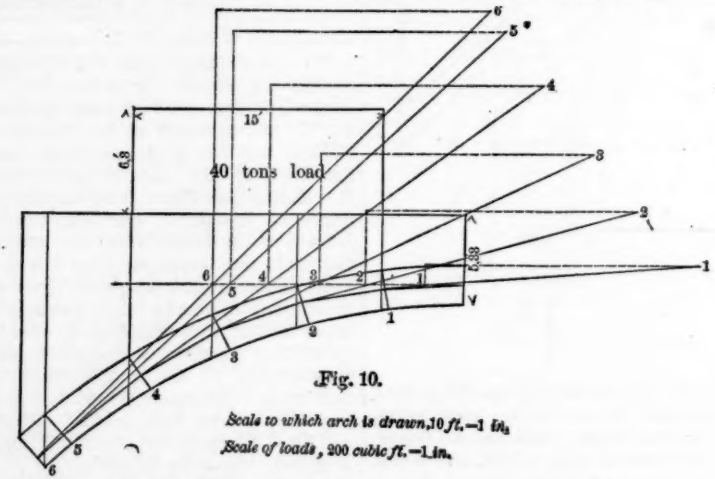



Fig. 10.

*Scale to which arch is drawn, 10 ft.—1 in.*

*Scale of loads, 200 cubic ft.—1 in.*

side of the crown, over divisions 2, 3, and 4, *i. e.*, 15 ft. along the rails. We shall suppose it to bear only on 6 ft. of the thickness of the viaduct. Calling the weight of a cubic foot of stone=.07 ton and $h$, the height of the block of stone 15 ft. long by 6 ft. wide that is required to weigh as much as one engine; we have

$$6 \times 15 \times h \; .07 = 40 \quad \therefore h = 6.3.$$

We now form the following table which refers to Fig. 10, which as the arch and load is symmetrical, represents, as before, only one-half the arch.

TABLE 2.

| | w | v | s | c | m | S | M | C |
|---|---|---|---|---|---|---|---|---|
| 1 | 5 | 5.4 | 27 | 2.5 | 67 | 27 | 67 | 2.5 |
| 2 | 5 | 12.4 | 62 | 7.5 | 465 | 89 | 532 | 6. |
| 3 | 5 | 14. | 70 | 12.5 | 869 | 159 | 1401 | 8.8 |
| 4 | 5 | 16. | 80 | 17.5 | 1408 | 239 | 2809 | 11.8 |
| 5 | 5 | 13.2 | 66 | 22.5 | 1485 | 305 | 4294 | 14.1 |
| 6 | 1.75 | 14.5 | 25 | 25 9 | 658 | 330 | 4952 | 15. |
| | | | 330 | | 4952 | | | |

A line of pressures passing through the middle of the crown, the point on the springing joint, as before, will be found to be contained inside of the limiting curves, and is drawn as in Fig. 10, taking care to lay off the centres of gravity on

the prolongation of Q. We find in this case $a = 25.6 - 15 = 10.6$, $P = 330$ $b = 10.7$.

$$\therefore Q = \frac{330 \times 10.6}{10.7} = 327 = \bigcirc = 23 \text{ tons.}$$

If it is desired to draw the curve corresponding to the minimum of the thrust in the limits chosen, we resort to equations (2) and (3). As the nearest approach of the last line of pressures drawn to the outside limiting curve, is at joint 2; pass a curve of pressures now through the point of intersection of that outside limiting curve with the second joint and the previous point at the springing joint.

We find $P = 330$, $a = 10.6$, $e = 9.8$ and from table 2, column (S) $P_1 = 89$; from column (c) and the drawing $a_1 = 9.8 - 6 = 3.8$.

From (2)

$$\therefore Q = \frac{a P - a_1 P_1}{e} = \frac{3498 - 338}{9.8} = 322$$

From (3)

$$q = h - \frac{a P}{Q} = 11.93 - \frac{3498}{322} = 1.04$$

Laying off this latter distance, from the summit of the arch ring, downwards, we draw the curve as before. It is everywhere within the proper limits. It is not drawn in the figure as it passes very near the first curve.

If we suppose an engine of 13.3 tons weight to rest on division 3 on both sides of the crown, along 5 ft. of the length of the rails, we shall find by forming a table and constructing the line of pressures as before, that it passes slightly below the upper limit at the crown, and is everywhere contained in the middle third of the arch ring.

A curve of pressures for a uniform load of 1.5 tons per foot along the whole length of the bridge, will be found to follow very closely the curve drawn in the first example.

One or two more suppositions of isolated weights, symmetrically placed, were made, but in all cases it was found that a curve of pressures could easily be drawn in the inner third of the arch ring. The thrust is too small to fear crushing, and the directions of the thrust are inclined to the normals of the arch joints at angles much smaller than the angles of friction, hence sliding is not to be feared.

We conclude that thus far the arch has stability.

9.—It occurred to the writer that if the actual line of pressure in an arch composed of incompressible voussoirs, touched the contour curves, as shown in Art. 5, that it should hold very nearly in the case of experiments with light wooden arches, whose weight is not sufficient to produce much compressibility. It will be seen that this law is beautifully illustrated by these simple experiments.

The experiments by the writer were made with great care to endeavor to meet the requirements of an exact science.

Mr. Wm. Bland has published in Weale's series a book entitled, "Experimental Essays on the Principles of Construction in Arches, Piers, Buttresses, etc.," (1867), which contains experiments that we shall quote from. The preference will, however, be given to the writer's experiments, as we do not know *what care* Mr. Bland used in cutting out the voussoirs, in keeping the span invariable, piers vertical, and applying weights, etc.

To avoid mistake, the following nomenclature will be adopted:

*Depth* of a voussoir is the dimension in the direction of the radius of the intrados $\perp$ to the axis of the arch.

*Thickness* of an arch or pier is the dimension $\parallel$ to the axis of the arch.

*Width* of a pier is its horizontal dimension $\perp$ to the axis of the arch.

*Height* is measured vertically.

The dimensions will all be given in inches.

A Gothic arch (Fig. 11) of 14 in. span, and 12.12 in. rise, was cut out of a poplar (tulip tree) plank, 3.65 in. thick, consisting of 8 voussoirs, each 3.65 thick, 2 deep, and 4.08 along their centre line from middle to middle of joint; each voussoir weighing .52 lb. Quite a number of voussoirs were cut out of the same layers of fibres and those selected that weighed exactly the same; the voussoir to be tried being hung to one end of a delicate balance beam, with a voussoir of the standard weight at the other end. The two voussoirs at the crown not being cut out of the same layers of fibres as the others, were shaved off about the middle of the extrados (not touching the joints) so as to weigh exactly 1 voussoir of the standard weight and their centres of gravity were found experimentally, and found to be at exactly similar points in both voussoirs, so that the entire arch was symmetrical as to the crown.

The centres of gravity of the other

voussoirs are taken on the arc of a circle passing through the middle of the joints and for any voussoir equidistant from the joints bounding that voussoir. For voussoirs whose sides are little inclined, this is sufficiently near the truth, and by dividing the arch ring into a sufficient number of artificial voussoirs, the result may be made as accurate as we please. Still as no wood is homogeneous the results can only be regarded as approximate as compared with the hypothetical homogeneous arch; still sufficiently near to establish the laws heretofore demonstrated.

When this arch was set up, the joints apparently fitted perfectly, and on placing a drawing-board by the side of the arch and tracing off its contour curves, it was found to be a perfect Gothic whose arcs, composing the contour curves were correct arcs of circles described from the springing points opposite.

A number of rectangular wooden bricks of exactly 1 voussoir in weight, of various sizes, were also cut out, as well as half bricks, quarter bricks, etc., and some solid rectangular piers of various dimensions.

A voussoir is taken as the unit of weight.

In experiments where weights were placed upon the top of the arch, an assistant added brick after brick, carefully balancing the load at the top on either side by the fingers, until the arch reached its *balancing point; i. e.*, the point where it stood with the weight, but fell with a slight jarring.

The two bottom voussoirs were, when necessary, kept from sliding by two fastening tacks being driven into the board on which the arch rested, pressing against the arch .03 above the springing line, or so little that it may be disregarded. The board was carefully levelled at every experiment by a spirit level, and the span kept invariably at 14 in.

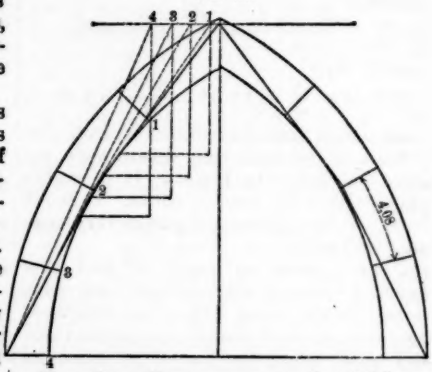
There was little or no vibration in the room.

*First Experiment.*—With 8.2 voussoirs on the summit of the arch it stood, though fell with 8.3 voussoirs on the summit; rotating on joints 2 on intradosal edge and at the summit; the arch being forced out at the haunches and falling at the crown. (See Fig. 11.)

The following table gives in its first column the number of joint from the crown; column *s*, the *elementary weights* (4.1 voussoir being the weight on the summit that goes to each abutment, the weight of each voussoir being taken as unity); column *m* gives the horizontal distance from the crown to the centre of gravity of each voussoir with its load, if any, which, in this case, is also the *moment* in reference to the vertical through the crown of each voussoir. Columns S, M, and C have been before explained.

| | s | m | S | M | C |
|---|---|---|---|---|---|
| | 4.1 | 0.00 | 4.1 | 0.00 | 0.08 |
| 1 | 1. | 1.70 | 5.1 | 1.70 | .33 |
| 2 | 1. | 4.68 | 6.1 | 6.38 | 1.04 |
| 3 | 1. | 6.79 | 7.1 | 13.17 | 1.85 |
| 4 | 1. | 7.88 | 8.1 | 21.05 | 2.6 |
| | 8.1 | 21.05 | | | |

Fig. 11.




Try a line of pressures, passing 0.1 from the upper edge of crown joint (*i. e.* at the *summit*) and 0.1 from the extrados edge of the joint at the springing. From the drawing and table we find $a=6.3$, $b=14.27$, from which equation (1) gives us

$$Q=\frac{8.1\times 6.3}{14.27}=3.57$$

The line of pressures drawn with this value of Q and passing through the points indicated cuts joint 2 at 0.1 from its lower edge. From joint 0 to joint 2 the line of pressures corresponds to the minimum of the thrust; from joint 2 to joint 4, to the maximum, for if the point of application at the crown is lowered to the point at joint 2, being moved from the edge, the same amount, the centre of pressure at joint 4 is moved to the left, outside its limiting position, which, as just seen, is in this arch 0.1 from the contour curves, for in *no other position* of the line of pressures than that first found, will it cut the

joints of rupture 0,2 and 4, at the same distance from the contour curves, which, as the material of the voussoirs is nearly homogeneous, it is reasonable to conclude, should be the case. As there can be no greater nor less thrust, we conclude that the arch is on the limit of stability, as the experiment indicates.

0.1 is $\frac{1}{10}$ of the depth of joint.

Sliding would have occurred on joint 4, as the resultant on that joint made an angle of 24 deg. with the normal, but for the tacks before mentioned.

The diagrams for this and all the following experiments were drawn to a scale of one-third the natural size, except in the case of some of the pier experiments.

*Second Experiment.*—With the two voussoirs at the crown in one solid piece, the arch could not give by rotation, as the lower edge of crown joint could not open. With a sufficient pressure on the crown, there was sliding along joints 4, the coefficient of friction being small for these wooden blocks.

We evidently have here a sufficient reason for making the keystone in one solid piece.

*Third Experiment.*—On placing a knife edge against a notch .03 deep, cut into the bottom voussoir, 0.4 above the springing line, on each side, the arch balanced with 11.1 voussoirs on the summit. The line of pressures must now pass through the knife edges, and it will be found on constructing a diagram that it will pass about 0.1 from edges at joints 0 and 2, as before.

*Fourth Experiment.*—(Fig. 12.) The same arch stood, being very nearly on the balancing point, on *solid* piers 10. high, 1.9 wide, and 3.65 thick, each pier weighing 2.3 voussoirs, the intrados at the springing being at the inner edge of pier. The piers were made vertical by a spirit level, and their tops were upon the same level, in every experiment given.

In the following table the pier is included opposite joint 5 of the first column.

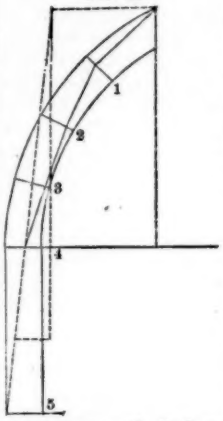
| | S | c | m | S | M | C |
|---|---|---|---|---|---|---|
| 1 | 1 | 1.7 | 1.70 | 1 | 1.70 | 1.7 |
| 2 | 1 | 4.68 | 4.68 | 2 | 6.88 | 3.19 |
| 3 | 1 | 6.79 | 6.79 | 3 | 13.17 | 4.39 |
| 4 | 1 | 7.88 | 7.88 | 4 | 21.05 | 5.26 |
| 5 | 2.3 | 7.95 | 18.28 | 6.3 | 39.33 | 6.24 |
| | 6.3 | | 39.53 | | | |

To pass a curve of pressures 0.1 from the edges of joints 0 and 3, which will be found to correspond to the minimum of the thrust, we find from the above table and the drawing

$$Q = \frac{3 \times 2.2}{10.5} = .63$$

from which the curve of pressures in Fig. 12 is drawn, as before. This curve approaches the intrados nearest at joint 3, cuts joint 4 at .58 from the inner edge, and the base of the pier .2 from the outer edge or about $\frac{1}{10}$ the width of pier.

Fig. 12.




*Fifth Experiment.*—With piers 40.47 in. high, 3.65 wide, and 1.9 thick, weighing 10.1 voussoirs each, with the intrados of arch at springing on a line with inner edge of pier, the same arch balanced. The pier was built of a solid block 22 in. high, and 5 bricks placed on top, one above the other to make up the 40.47 in height.

A line of pressures drawn .1 from summit and .1 from intrados at joint 3, passes .5 from outer edge of pier, or about $\frac{1}{7}$ width of pier.

It will be found on constructing the diagrams for Mr. Bland's experiments, where the piers were built up of bricks, that in the case of low piers as in Figs. 51, 52, 53, 54, 55, 45 (*Exp.* No. 5), and 46 (*Exp.* 8), the line of pressures passes very near the outer edge of the base of the pier; but as the piers were increased in height, this line approaches more and more the centre of the base, being in the case of a pier 6 × 6 base and 72 in. high, nearer the centre of the base, than its outer edge.

It is probable that this is caused by the outer edge of every brick, when the line of pressures passes on that side of the centre, *compressing* a small quantity, as a great many irregular surfaces of contact must cause a greater compression than if the pier was solid. Again, the additional pressure on the lower bricks of a high pier is an evident cause for greater compression than with a low pier. A high

pier of many bricks appears to *bend* in consequence of that compression of its many edges. It may be inferred from these facts that the greater the thrust in an arch the farther the line of pressures retreats within an arch; which we shall find to be so in the sequel.

*Sixth Experiment.*—The pier of *Exp.* 4 (Fig. 12) was moved outward (*from* the axis of the arch) so that when its inner edge was .1 from the springing, it stood with no weight on the summit; when it was .4 from edge, it stood with .5 vs., fell with .6 vs.; .5 from edge, balanced with .75 .vs.; .6 from edge balanced with .75 vs.; .7 from edge balanced with .37 vs.; 1.0 from edge balanced with .12 vs.

From which we infer that the centre of pressure at the springing joint is .5+5.1 (to allow for compression)=.65 from inner edge of joint for a weight of .75 vs. on the summit or apex of the arch. On constructing the table and diagram for this weight it will be found that theoretically the centre of pressure at the springing joint is .63 from the inner edge, which differing only .02 from the distance found by experiment must be regarded as a beautiful experimental illustration of the theory.

*Seventh Experiment.*—The same arch stood easily with .75 vs. on the summit, on solid piers, 22. high, 3.65 wide, and 1.9 thick each weighing 5.1 vs.; the arch fell with the addition of .12 vs. more.

On constructing this figure it will be found that the line of pressures, assumed 0.1 from edges of joints 0 and 3 as before, passes .63 from inner edge of springing joint (as was stated above) and cuts the base of pier .39 from its outer edge or about $\frac{1}{3}$ the width of pier.

*Eighth Experiment.*—On moving this pier back as in the 6th *Exp.*:

| | | | | | |
|---|---|---|---|---|---|
| 0.47 | the arch | balanced | with | 1.12 | vs. |
| 0.53 | " | " | " | 1.25 | " |
| .59 | " | " | " | 1.25 | " |
| .63 | " | " | " | 1.25 | " |
| .7 | " | " | " | 1.12 | " |
| 1. | " | " | " | 1.00 | " |

Taking .58 as the probable distance and adding .1, we get .68 as the probable distance back from the springing to the centre of pressure of joint 4. On constructing the line of pressures for a weight of 1.25 at the apex, passing 0.1 from the edge of joints 0 and 3 as before, it will be found that the centre of pressure on joint 4 is .7 from the edge, which is again a most striking coincidence, as it differs but .02 from the joint found experimentally. These experiments were made with great care, keeping the span exactly 14 inches, piers vertical, etc., etc.

Compare similar experiments by Mr. Bland (Figs. 56 and 57), where the same law is established approximately.

It is evident from an inspection of the arches in churches (for examples see drawings in the latter part of Mr. Bland's treatise) that constructors were well aware that a higher pier might be used when its inner edge was moved back a certain distance from the springing, which is equivalent to what we have established above.

*Ninth Experiment.*—With the pier used in *Exp.* 4, and the same arch, excepting that the two voussoirs at the crown were in one piece, the arch and pier just balanced as in *Exp.* 4. In fact, the arch and pier can easily rotate on the third joint and the outer edge of pier.

*Tenth Experiment.*—The same arch with piers 1.98 wide, 7.5 high and thickness of arch, each weighing 2 vs., stood easily when a cylindrical pin .03 in diameter was placed at the lower edge of crown joint. This joint bore at no other point, hence the line of pressures presses through the pin. Assuming it to pass .1 from the edge of joint 3, the construction will show that it cuts the springing joint .6 from inner edge and the base of pier .15 from its outer edge.

The *experiments* that we have just considered, very clearly indicate the fallacy of that theory which supposes that if a line of pressures passes outside the inner third of the arch ring, *that it must fall.* On the contrary, in every case of stability of the arches previously given, it is *impossible* to draw a line of pressures everywhere contained within the inner third of the arch ring. In fact, if such were attempted it would be found in every case that such a line of pressures would pass *outside* the base of the piers, or of the arch if used alone.

It is hardly probable, in most actual arches, that this line of pressures ever keeps within the inner third.

Theoretically, for the voussoir arch, there is no foundation for such a theory, and we confess to astonishment when we read in Prof. Rankine's "Engineering," Art. 280, "It is true that arches have stood, and still stand in which the centres of resistance of joints fall beyond the middle third of the

depth of the arch ring; but the stability of such arches is either now precarious, or must have been precarious while the mortar was fresh."

As we have just asserted, in our experiments "the centres of resistance of joints" invariably fall outside the middle third, for certain joints, and if an experiment were made with a 50ft. arch it is not probable that at the joints of rupture, the centres of resistance would be found as far back from the edge as $\frac{1}{3}$ or even $\frac{1}{4}$ the depth of joint.

It may be well enough on account of the shocks to which bridges are subject to design an arch in which a line of pressures may be drawn within the inner third, but it is by no means necessarily true that the line of pressures can never pass this limit without the stability of the bridge being rendered precarious, though it would seem that this error has likewise been received in France (see "Traité de la Stabilité," etc., p. 220) by eminent mathematicians.

This subject will be referred to again in Art. 10. In all the experiments with arches the same voussoirs were used in the same positions each experiment.

Every experiment is given that was made, so that the reader may judge for himself how far the theory of Dr. Sheffler is established. No force diagram was drawn until after, and in some cases long after, the experiment was made; and no second trial was resorted to in any case.

All other writers but Dr. Scheffler, so far as the writer knows, have left the true line of pressures, in many cases at least, perfectly *indeterminate*, and it is Dr. Scheffler who has raised that indetermination by means of the principle of the least resistance and given us a theory which is upheld by experiment. Some authors actually assume the line of pressures to pass through the middle of the joint at the crown and springing.

It is evident how much more incorrect this is even than the fallacy of the "midole third."

[To be Continued.]

## IRRIGATION WORKS IN THE BATTICALOA DISTRICT OF CEYLON.

By Captain W. PHILLPOTTS, R.E.

From the Papers of the Royal Engineers.

To assist in developing the resources of a semi-civilized country is one of the most interesting of the very varied duties we can be called on to perform in our distant colonial possessions. The means of doing so varies with the nature of the country; but in the tropics, I know of none which goes more directly to this object than giving to a capricious and fitful stream a certain supply of water, and thereby rendering the land through which it flows capable of profitable cultivation. This is particularly the case in the East, where rice is the staple production, for there is no other species of cultivation which requires such a regular and constant supply of water to bring it to perfection.

The necessity of irrigation works in the East has long been recognized as paramount. No matter what the vices of ancient governments have been, they must at least have the credit of having constructed some of the most gigantic and successful hydraulic works in the world. We read of these as occurring in many parts of India, and from personal observation I can testify to the magnitude, durability, and skill evinced in similar constructions by the ancient inhabitants of Ceylon; and I much doubt if any other countries of similar size present specimens of finer engineering works than are there shown by the dams, canals, and tanks, or, as they would be more appropriately termed, lakes, with which it abounds. These ancient works are, however, mostly partially in ruins, after centuries of neglect and decay, but even in their present state they testify to the extraordinary boldness of conception which initiated them, as well as to the enterprising skill displayed in their execution.

It would require a history of Ceylon to trace the causes of their destruction, suffice it to say, that constant wars and bad government so reduced the population, that cultivation was partially abandoned, then disease followed, and carried off its thousands; whole districts were deserted by their inhabitants; the works themselves fell out of repair; nature, left to itself, rapidly changed fertile fields to jungles infested with wild beasts, so that now the finest hunting grounds which the

sportsman visits are in the midst of the most interesting remains of the former grandeur of the country.

The Batticaloa District, which is on the eastern side of the island, is particularly adapted for the growth of rice, so much so that it has long been called the granary of Ceylon. Up to the date of Sir Henry Ward's government, 1856, no permanent works had, however, been undertaken for its irrigation. Here were no vast ruins as in other places, which was to be accounted for by its remoteness from the ancient seat of government, and its comparative natural facilities for rice cultivation. It was, however, acknowledged that certain works, comparatively small, would be of immense service to the district; and the governor, having convinced himself of the necessity of these by personal inspection, in company with Major Gossett, the surveyor-general, at once authorized their execution. I do not for a moment mean to say that these works bear any comparison with those executed under the ancient kings of Ceylon, but they were the most extensive, and the only systematic ones, which our government had undertaken, so that I must confess to have been gratified to find myself placed in charge of them, and I venture to hope that a description of them will not be uninteresting.

Our predecessors in the rule of Ceylon —the Dutch—with their usual sagacity and skill where any hydraulic works were necessary, had devoted the most unceasing care to the irrigation of this district, the fruits of which were shown by the quantities of grain it produced. Strange to say, however, their works were not of a permanent character, and their dams were merely mounds of earth, without any masonry. This can only be accounted for by the absence of skilled artificers, and the abundant population of common field laborers; the former could only have been imported at great cost, while the latter were always available, and could be employed without any expense whatever. This was owing to the system of Rajahkaria, or forced labor, which gave the chief officer of the district power to call out as many men as he wanted to repair or construct any works necessary for irrigation. These men got no pay, each landowner having to supply them according to the quantity of land he possessed, and as the works were entirely for their benefit, they were glad enough to have the labor combined for the common weal. The system followed was this, after the great periodical rains and floods, the dams of the tanks were repaired, and as much water stored in them as circumstances permitted. In the dry season the dams were cut, and the water allowed to run off to the river, which conveyed it to the fields. The next floods, while they refilled the tanks, breached the dams, which had again to be repaired, and thus it went on from year to year. It is superfluous to point out the inconveniences of such a system as this, the waste of labor must have been enormous, and it was never possible to keep the tanks full, on account of the difficulty of repairing the dams before a quantity of water had run out, added to which, the floods were so uncertain that the repairs had to be made two or three times for one crop.

The English, on succeeding the Dutch, pursued much the same system until the abolition of forced labor in 1836; this put it out of the power of government to work men without pay. The legislature would not incur the heavy annual outlay which the alteration of the law called forth, and no steps being taken to collect the necessary labor, the tanks became useless, the supply of water most uncertain, and in bad seasons the cultivators were reduced to the greatest privations. Although when Sir H. Ward visited the district in 1857, the tanks had long ceased to be of any use, yet most distinct traces of their existence remained; these in a few years had become covered with jungle, and formed the abodes of the various wild animals with which this part of Ceylon abounds. But even had the works been utterly obliterated, those were living who had seen them in action, had preserved a grateful recollection of their effects, and had long cherished the hope of their restoration, now speedily to be realized. The scheme, therefore, which the government had to decide on was eminently a safe one, inasmuch as the good effects of the Dutch works were universally acknowledged; that it would prove a remunerative one was also probable, for by extending the works a large amount of crown land would become capable of cultivation, and be eagerly purchased by the natives, while by increasing the capa-

bilities of existing fields, the value of the tithe due as a tax to government would also be enhanced.

The lands to be irrigated were all dependent on one river, the Pattepola Aar, for water; this river takes its rise in the south-east portion of the interior table land of Ceylon, and like all other rivers there, has a very precipitous course until it reaches the low flat country along the sea coast, which it does about 40 miles from its mouth. Here the banks become low, and the course tortuous, but its general direction is north-west, until it expands into a large lake running north and south, at the north end of which it joins the sea. The land on its banks is rich alluvial soil, the very best for the growth of rice, and the deposits left by the floods have the most fertilizing effect. Before entering the lake just alluded to, it forms a delta, intersected by numerous watercourses, all supplied by the same river. The river has the peculiarity which is, I believe, common to all the deltaic rivers, its proper bed is elevated above the surrounding country, so that its course may be said to extend along a ridge; this is caused by the constant deposits left by the floods year after year, and it shows itself at once by the inclination which the stream has to burst away from its channels. This peculiarity has its advantages, as it greatly facilitates bringing water to the land, for it is obvious that as long as water could be kept in the main channel, it can always be drawn off to land below that level. The object of the works was, therefore, to give the means of sending a supply of water into the river whenever it ran dry, and confining it to the main channel.

During the rainy season, from November to February, the river was generally full; and it was also during this season liable to the most violent and sudden floods, which inundated the country for miles. In March and April the supply of water became uncertain; in May the river generally ran dry, and remained so, with the exception of an occasional fresh until November. A small, but certain, supply of water during these dry months was all that was necessary to make the land the finest rice country in Ceylon. To meet this supply it was determined to restore two of the largest old reservoirs which the Dutch had used, called the Tanks of Erecamam, and Ambarree. It was thought at the time that if these two sites were made the most of by efficient permanent works, that sufficient water would be secured, and subsequent experience proved this correct.

I shall now proceed to a description of these tanks, premising that the word "Tank," as used in the East, means a large reservoir some hundreds of acres in extent. The usual way to form a reservoir, is to build a dam across a valley, and thus intercept the water flowing from the surrounding hills, a stream generally being taken advantage of to secure a constant supply. The height of the dam is determined by the quantity of water required, care being taken to provide spill-waters to prevent the water rising above its proper level, and thus breaching the bund.

Erecamam Villoo, as it was called, was an exception to this rule, being peculiarly situated; it was not a valley, nor did any river flow through it. It was a large hollow plain or basin, 1,000 acres in extent, on the river's bank. Low, undulating wooded hills surrounded the plain on all sides, with the exception of about three-fourths of a mile, where it had the river for its boundary. When the river rose over its banks, it filled the plain, which again became dry on the flood subsiding; it was, therefore, necessary to adopt some means which would let the flood in, and when in to keep it there until required. In the course of time the river had worn a narrow channel into the plain, and through this a large quantity of water found its way, still more, however, ran over the low flat land adjoining the river. It will be remembered that the Dutch had used this tank, and when I first visited it the line of their bund was clearly seen. It was breached in numerous places, and was merely a succession of isolated mounds of earth covered with trees. A new bund was built along the line of the old one, and its height was fixed at 24 feet above the river's bed. The level of the tank was fixed at 9 feet below the crest of the dam, which being level terminated at either end, when the line of the crest came to within 9 feet of the natural ground; these ends were protected by circular retaining walls, and the ground beyond levelled for about 40 yards, so as to allow the floods to flow

freely round the dam. They, in fact, became spill-waters over the natural ground. The floods usually rose two or three feet above this level, but as that was not always to be relied on, the channel before referred to as leading from the river to the tank was kept open, and provided with flood-gates to be closed as soon as the tank was full. The height of the dam varied from 9 to 24 feet, and its length was half-a-mile, its slopes were 2 to 1 on each side, and its width at top 6 feet. It was composed of a stiff clayey soil, got close at hand, and carefully watered and rammed in horizontal layers one foot high; when finished the sides were planted with grass, which grew very rapidly and formed a capital protection for it. The excavation and carriage of the earth to form the dam cost from 3½d. to 6d. per yard cube. A sluice in brick masonry, with two water-ways 6′ × 4′ was built in the bund. This was provided with doors sliding in grooves so as to command the supply of water. The channel communicating with the river varied from 60 to 70 feet in width, and 8 to 12 feet deep. In designing the flood-gates for this channel, the object was to keep the waterway as wide as possible, and the scarcity of skilled labor necessitated their being as simple as possible. I first thought of making them a series of doors hung on pivots above the centre of gravity, so as to be self-acting, but the quantity of logs brought down by the floods rendered this inexpedient. I therefore adopted the plan of making the gates to consist of single horizontal planks, supported at either end by a pier of masonry, and intermediately supported by wooden posts so arranged as to make the plank a manageable weight for two men. The total width of the gate was 63 feet, and this was divided into 3 spans 17 feet wide by two 6-feet brick piers. Each of the bays was divided into three by two upright posts strutted to the apron, and the planks rested against them, so that they were supported every five feet. The planks were fitted with iron hooks for raising and lowering them. The apron was kept on the same level throughout, which was six feet below the level of the tank; this was 30 feet wide, and, of course, extended completely across the channel; the junction with the banks being protected by retaining walls carried well into the firm soil. This was very important, inasmuch as the whole work would be completely inundated in floods, and have 3 or 4 feet of water over its top rushing into the tank at the rate of 6 or 7 miles an hour. The apron consisted of three brick walls, 6 feet thick, and 6 feet apart, varying in height from 3 to 4 feet. Transverse walls 3 feet thick were built to connect them, and the intervening spaces filled with well-rammed clay. The foundation of this work was not difficult, inasmuch as decomposed granite rock was found in the bed of the channel, of sufficient hardness to give a firm base, and yet yielding to a well-pointed pick. In one part sound rock cropped out at an angle of 18°, this was prepared for receiving the first course of masonry by throwing in brick concrete. The apron was paved partly with brick on edge and partly with stone, the latter being used when the water fell over the dam. This work was about 400 yards from the end of the dam, and the intervening ground being flat, and rather above the level of the tank, was left as it was to admit of the floods flowing over it as freely as possible. At the other end of the dam was another channel, but much smaller, and on a higher level; a small work was built here on the same principle as the larger one, with the addition of raising the piers and abutments to support a bridge. Before deciding on these works, I had an opportunity of observing the river in flood, as I lived on the spot during a rainy season, before doing anything more than commencing the bund. A continuous residence there of 3½ years confirmed the view I first formed. Knowing the river so well was of the utmost advantage to me, as the description of its state during the rains, which I had received from natives, gave a very faint idea of the violence and extent of the floods to which it was subject. I was completely astonished on witnessing the first flood. For some four months before no rain had fallen, the river was dry, the wells dry, and all vegetation completely shrivelled up; for about a month even the dew, that beautiful source of moisture in a tropical climate, was wanting. The rain set in about the middle of November, and in its first burst it was an incessant down pour for seven days; about the fifth day the river began to rise above its banks, and in the next 36 hours it rose with marvellous rapidity, completely inundating the country for miles around, and surrounding my camp, which I had pitched

on a flat hill, with water to within 6 feet of its summit; all communication was stopped except by canoes, but it was only possible to work these down the stream on account of the strength of the current. On the 8th day the rain ceased, and the river fell as rapidly as it rose, and in a few days the face of the country was completely changed.

The foundations of the sluice and upper gates were also brought down to the rock, which at these places rose to near the surface. You will find drawings of all these works, showing their construction, in detail.

AMBARREE VILLOO.

I shall not go so minutely into this, its situation being similar to Erecamam. Everything connected with it was designed on the same principles, but on a smaller scale. You will find plans of all the works connected with it on the table.

It was very interesting to watch the effects of the various works the first flood after their completion. The river rose with its usual violence, the waters rushed into the tank through the flood-gates, but before the tank filled these were completely flooded, and almost unapproachable, the bund was surrounded with water, which rushed into the tank round the retaining walls at either end. Soon after the flood was at its height, the water on either side of the dam seemed to be at rest for a few minutes, then it rushed out by the same way as it came in, until it had subsided to the level of the ground at either end, and the top of the flood-gates; these were at once closed, the operation being performed easily by four men, notwithstanding the rush of water through them. The tank was now full, the water extending some distance into the jungle which bounded the plain of Erecamam, necessitated the abandonment of a village on one side of it.

On one side of the plain of Ambarree was a very sacred small stone idol in the figure of a man; it had been there for ages, and the natives used to come for miles to make offerings to it. During the progress of the works, and by questioning me on the subject, they found that the water line of the tank would just reach the god's chin. Here was a dilemma, either the god must be moved from the position he had occupied for centuries, or he must be immersed in water half the year. Recourse was had to the oracle of the temple, who decided that he was to remain in his watery position.

The area of the plain of Erecamam was over 900 acres, but the surface covered with water was between 1,300 and 1,400 acres.

In Ambarree the area of the plain was 600 acres, and of water when the tank was full, between 800 and 900 acres. The calculated contents of the two tanks, when full, are nineteen million cubic yards of water in Erecamam, seven millions in Ambarree.

A watercourse was cut from the sluice of each tank to the river, so that this quantity was under perfect command to supply the river when it ran dry, during the cultivation season.

I shall not attempt to describe the delight of the people at seeing such a quantity of water stored up for their cultivation; they felt that they were now certain of tilling their land profitably, and they gave substantial proofs of this by their eagerness to buy up the crown lands, a statement of the proceeds of which I shall presently give.

VEREADDY CATTOO OR DAM.

The only formidable escape of water from the main channel of the river was down the branch called the Vereaddy Aar, running into Akrapattoo, the slope of this branch was so rapid that it took off a very large quantity of water, much more than the land through which it flowed required, while for six or eight months in the year it completely drained the Sengepaddy Aar, or upper stream, to the great injury of the Carawagoo lands. The former land had too much water, the latter not enough, to equalize the supply; it was, therefore, determined to construct a regulating dam at its head. This was not intended to prevent the heavy floods going down the Vereaddy river, for that would have been impossible, but it was simply to prevent such portions of the summer freshes as were not wanted in Akrapattoo, and thus to force them into the Sengepaddy river.

The design for this work required careful consideration, on account of the quantities of sand brought down by the floods. A simple wall with sluices and aprons across the river's head might, for a few years, have answered the purpose, but the sluices would constantly have been choked with sand, and the dam itself would have presented a most formidable obstacle to the

winter floods, which it was useless to attempt to stop; I therefore determined on a work similar to the flood-gates at Erecamam, that is a dam composed of masonry piers, and wooden posts supporting horizontal planks, to be removed singly. During the season of floods, the dam is kept entirely open by taking out the planks, it then presents to the stream no more obstacle than a bridge would do; the floods are thus freely allowed to flow off, and there is no accumulation of sand above the dam. You will find a detailed plan of this work on the table. The only thing in which it differs essentially from the work at Erecamam is the foundations; here the bed of the river was loose sand from 9 to 10 feet deep, when clay was reached. In the foundation I adopted the plan almost universally pursued in Southern India, viz.:—continuous wells sunk 9 to 10 feet in the river's bed. Two rows of wells were sunk across the river to correspond with the width of the apron, intermediate wells for the piers being also sunk; these wells were then filled up with a mixture of clay and broken brick, and the apron, 3 feet thick, was built upon them in brick masonry. This system of foundations is particularly well adapted to rivers of this kind, and is almost universal in the Madras provinces; it was the first time, however, it had been adopted in Ceylon, and I was obliged to get the workmen from India. There is a class of men who do nothing else, and are in consequence called well-sinkers. The first two or three feet can be sunk by any intelligent workman, but after that the men work under water by diving, and it is only those who are accustomed to this sort of work who can stand it, and even to them the work is so severe that they have constantly to be relieved. Strange to say, what they suffer most from is cold, and that with a blazing tropical sun over them sufficient to raise the temperature to 110° or 120°. They work naked, and when they come out of the water the evaporation from their skin is very rapid, this makes them intensely cold; they adopt a novel means of warming themselves; as soon as they come out of the water, they cover themselves with hot sand, and there lay until their turn comes round for work. As a rule, three men work at each well, one of whom is always resting in this way. Physically, they are a fine race of men, and are all but amphibious.

Vereaddy Dam has completely answered the purpose for which it was designed; it affords the means of throwing five feet of water into the Sengepaddy river, a quantity amply sufficient for all the land through which it flows, and by simply withdrawing the planks the quantity of water going into the Vereaddy Aar can be regulated with the greatest nicety. The first closing of this work was not less interesting than that at Erecamam; the position of the two rivers was reversed, the branch which had before carried off all the water was now dry, it being forced into the Sengepaddy channel, and the delight and surprise of the natives at seeing the hitherto unruly river brought under control was most gratifying. It was curious to see how the fish were deceived by it, numbers were caught just above the dam, while others, in their attempts to pursue their accustomed haunts, got jammed in between the planks, or found themselves landed on the nearly dry apron below.

The chief difficulty experienced in carrying out these works was the scarcity of skilled labor; this had to be brought from the south of India at great cost. The unhealthy nature of the climate was also a great drawback, and it was quite melancholy to see how the workmen suffered. I believe this will always be the case in carrying on works in a wild part of a tropical country; I had sad experience of it here among my men, although the works were not more than ten or fifteen miles from thickly populated and healthy villages. The materials used were bricks, stone, and lime, the former were taken from some ruined temples in the vicinity, but the lime had to be transported partly in boats and partly on bullocks' backs a distance of 50 miles. It was burnt from coral, and very excellent mortar it makes; to render it more hydraulic, I mixed brickdust with it, generally in the proportions of 2 of brickdust, 1 sand, 2 slaked lime.

In considering artificial irrigation for rice, the question will naturally arise, how much water is necessary, say for an acre. This must vary in different countries, besides which, some kinds of rice require much more water than others. In Ceylon, even the statements given me on this subject by intelligent farmers differed greatly, the most reliable information I could procure, however, made it appear that an acre of rice required a supply of 4,000 cubic

yards of water, extended over a period of 90 days. General Cotton, the great irrigation engineer of Madras, gives the quantity at 5,000 cubic yards, while the late Colonel Baird Smith, equally celebrated for his works in Bengal, states that a cubic foot of water per second is sufficient for 40 acres. It is so impossible to reconcile these statements, that the discrepancy must arise from different systems of cultivation. In Ceylon a constant supply was not required.

In conclusion, a brief statement of the financial results of the works will be interesting. They cost £16,600. For the 10 years previous to 1861, the goverment tithe on the lands watered by the works averaged £1,805 per annum; in the year 1861 it was £2,055, being an increase of £1,250 per year, which the works secured to the revenue of the province. This £2,055 represents the annual tax on 14,000 acres of ground which were in cultivation before the works were commenced, but which were effected by the works, inasmuch as they afforded a certain supply of water, instead of the hitherto precarious one. Besides this, some 6,000 acres of crown land were rendered capable of profitable cultivation; a considerable portion of this had been sold in 1861, and realized £9,046, and as soon as it came into cultivation it would yield an additional revenue to government of from two to three shillings per acre. The financial results, therefore, have been very sat sfactory, and the social benefits conferred on the natives by encouraging them to adopt settled and permanent cultivation as a means of subsistence are incalculable.

Since writing this paper I hear that recent experience shows the result of these works in a still more favorable light. A statement, proving their utility and success, was made by the Surveyor-General on the 20th December, 1862, when the vote for the up-keep of the works was brought before the Legislative Council of Ceylon; and as it points out most clearly the benefits—both financial and social—resulting from the works, I cannot do better than conclude this paper with an extract from the Surveyor-General's own remarks on the occasion.

He said: "I am glad that my honorable friend has brought forward this subject, because I believe an inpression exists abroad to some extent that the returns from these works of irrigation have been quite inadequate to the outlay. I cannot think so myself. Both the works of Erecamam and Orrobokke are, in my opinion, decidedly successful. I cannot say the same of Devittore; still nothing as yet has been brought to account there.

"The returns show that £10,000 have been received from land sales and fees at Erecamam, against £18,000, the cost of the works and up-keep to date. Besides which there ought to be considered the increase to the annual revenue from the augmented taxation. Formerly 1s. was levied per acre over the 10,000 acres of old paddy land in the irrigation districts. It was proposed that this should be raised 2s. 6d. on account of the works, and that this rate should be exacted from the new lands. This should give an increase of more than £1,000 a year. I do not know for certain whether the rate has been raised to this figure, but I believe it has been. Then in 1858, 1860, and 1861, the country was visited with severe drought, and the crops of those years were entirely due to the successful operation of the irrigation works. When in Batticaloa, I was told that the value of the crop might be estimated at £20,000; so that these works have been the means of saving £60,000 to the native inhabitants of that district. It is not difficult to find out the value of a crop in money, but who is to estimate the amount of privation and even mortality that would have ensued had these works not been constructed."

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Russia possesses a remarkable system of river, canal, and lake communication, the importance of which has not been destroyed by the railways. The configuration of the ground, mostly flat, is very favorable to navigable water-routes, which attain in the country a total length of 34,770 kilometres, or 1 kilometre per 143.7 square kilometres of territory, and for every 1,831 of the inhabitants. To appreciate these numerical results, however, regard must be had to the average length of season in wh ch navigation is practicable; this is in Russia, only 239 days in the year. In the north the fluviatile communications are possible only 6½ months; in the south (on an average) 9 months.

# LOCOMOTIVES FOR ASCENDING STEEP INCLINES WITH SHARP CURVES.

By Lieut. J. G. HALL, R.E.

Papers of the Royal Engineers.

Not many years ago it was supposed that the adhesion between the driving wheels of an engine and the rails was such as not to allow of railways being worked with steeper gradients than 1 in 120 or 1 in 100, but practical experience has lately shown the fallacy of those ideas. Numerous samples may be cited of railways, both in Great Britain and abroad, where the gradients range from about 1 in 60 to 1 in 30, but I shall confine myself to a few of the most important ones, with a short description of how each is worked. Beginning first with those at home, we have the St. Helen's Railway. With regard to this line, the *Times* says:—"This line running through a hilly, mineral district, has a most remarkable combination of sharp curves and steep gradients. In a length of about 30 miles it has a constant succession of curves, varying from 500 down to 170 feet radius, and it has gradients from 1 in 85 to 1 in 35. This line has been usually worked by short engines on *six wheels*, four of them being coupled as drivers, and connected to separate tenders for the supply of fuel and water; the length of the wheel base of the engine was 12 feet. Even this comparatively short length of engine was disadvantageous on curves, involving much impedimental friction; and a still greater disadvantage was that tender engines are only adapted to run safely with the tender behind, and in the working and shunting, the loss of time, labor, and the expense was considerable. In lieu of those six-wheeled engines, a locomotive of quite a novel construction has been lately introduced. This engine is capable of running either end foremost, and of passing with a free, rolling movement round curves of two chains. The engine is on eight wheels, covering a base of 22 feet, and the length of the solid frame is 32 feet in length. The four central wheels have their axles, which are rigidly parallel to each other, passing through before and behind the fire-box, the axles being about 8 feet apart. It is quite obvious that so long an engine could scarcely pass round curves at all, even at any cost of friction, with the ordinary construction of wheels and axles. This difficulty is got over in the following way:—The tires of the four centre wheels already mentioned are applied on hoop springs of elastic steel placed between the wheel and tire. On these springs the tires can slip or revolve without sliding on the rails, and thus the revolutions of the tires are adjusted to the varying lengths of the rails on curves by self-action. The sliding of the wheels on the tire is not found in any way to impede the tractive power of the engine, but, on the contrary, rather to increase it. The extreme pair of wheels at each end have the same arrangement with regard to the tires, but the axles have very long bearings, and the boxes in which they run, instead of being parallel to the axles, are formed in curved lines struck from central points, and are permitted to move in this curvature through the horn plates and axle guides beneath the spring shoes. The result of this is, that the wheels and flanges are free to follow the curve of the rails, with this very important advantage in point of safety, that the extreme axles on curves always point truly to the centre of the curve, and, consequently are square to the rails even though the curve may be in the form of the letter S, requiring the axles to radiate in opposite directions."

Among other steep inclines in this country may be mentioned the Lickey incline on the Birmingham and Gloucester Railway. It has a ruling gradient of 1 in 37, and is worked by two locomotives coupled together, one of them weighing 35, and the other 32 tons, and they take up an average goods train, which is about 300 tons load, at a rate of 6½ miles per hour. The Dainton Incline, on the South Devon, is also very steep, being 1 in 45; and there is also an incline near Oldham, on the Manchester and Oldham Railway, with a gradient of 1 in 27. Most of these

inclines were formerly worked by stationary engines and rope traction, but this method of working inclines has fallen into disuse from two primary causes:—1st, that locomotives can do the work as well, and are more convenient. 2nd, Where the curves are numerous and sharp, it becomes almost impracticable to use a traction rope. Another reason might also be urged, that there is always a risk of the rope giving way and thereby causing very serious accidents.

Abroad steep inclines are becoming very common, and it is abroad that some of the most remarkable are to be found. The three following are the most worthy of notice, viz.:—the Semmering incline on the Vienna and Trieste railway, the Giovi incline on the Turin and Genoa Railway and the Bhore Ghaut incline on the Great Indian Peninsular Railway. The Semmering incline was opened in 1854; its entire length is 19.47 miles, and the gradients range from 1 in 40 to 150. The curves range from 9½ chains radius to 14 chains radius. It is at present worked by an engine designed by M. Engerth, the Austrian Government Locomotive Superintendent. The following is a brief description of the type of engine used:—It consists of two parts, the forepart carrying the boiler, fire-box, &c., is supported on three pair of coupled wheels, and the hind part is a peculiar description of "bogie" which carries the driver's platform and fuel, and is supported on two pair of wheels. The water is carried in tanks at each side of the boiler, so that the whole weight of boiler, tank, &c., is available for adhesion. The total weight of the engine, when filled, is 55¼ tons, and is distributed in the following manner: 13½ tons on the leading wheels, 12¼ on the centre, and 13 tons on the driving wheels, and 8¼ tons on each pair of trailing wheels. These two pair of trailing wheels were afterwards made into assistant drivers by means of axles with toothed wheels keyed on them. The total heating surface is 1,669 square feet, of which 75 square feet is fire-box surface. The number of tubes are 189 of 2 inches diameter, and 15 feet 7 inches in length. The grate area is 12 6 square feet, or 1⅓ of the heating surface. The diameter of the cylinders, which are outside ones, is 18·7 inches, and the stroke 25 inches. The wheels are all 3 feet 7¾ inches in diameter. These engines are 380 horse power, and can draw a load of 160 tons (engine included) up an incline of 1 in 40 and at a speed of about 10 miles per hour. About .73 cubic feet of water per horse power is evaporated per hour.

"The Giovi incline on the Turin and Genoa Railway commences about 7¾ miles from Genoa, at a point 295 feet above the level of the Mediterranean. It ascends there for about 6 miles to an elevation of 1,1°4 feet, being an average gradient of 1 in 36." The steepest gradient is 1 in 29, and the smallest 1 in 50. These gradients have curves of a minimum radius of 20 chains.

The locomotive power employed for ascending the incline, is obtained by using two engines of the same size, constructed by Messrs. Robert Stephenson and Co., of Newcastle, each carrying its own coke and water, and resting on *four coupled* wheels, with outside cylinders. The wheels are 3 feet 6 inches in diameter, and the cylinders 14 inches, the length of stroke being 22 inches. These two locomotives are bolted together, so that the fire-boxes are opposite each other, and they are manned by one driver and a stoker. When filled they weigh altogether 55¼ tons; the wheels nearest the fire-box carrying about 14 *tons* each, and the other 10 *tons*. In fine weather the locomotives carry up 100 tons, and in the worst, never less than 70 tons at a speed of 15 miles per hour.

*The Bhore Ghaut Incline*, by which Bombay is put in immediate connection with the Deccan, is 15¼ miles long, rises 1,831 feet with an average gradient of 1 in 48, the steepest being 1 in 37. It was opened in March, 1863, after having been in hand for 7¼ years.

The engines with which this incline is worked are *fourteen* in number, worked in pairs by coupling them back to back. They carry their own water tanks and are without tenders. Each engine has two pair of coupled wheels, 4 feet in diameter. The cylinders are 15 inches in diameter, and length of stroke 22 inches. The total weight of each engine when in working condition is 34½ tons.

Abroad great attention has been given to the construction of locomotives for ascending steep inclines with sharp curves, and, as a class, they are quite different from those used in this country.

On the *Northern Railway* of France, for instance, some of the heavy gradient locomotives have as many as *six* pair of wheels, coupled in two sets of *three*, with two pair of cylinders, and the fore and hind axle boxes have 1¼ inch play transversely to admit of their running round sharp curves of 600 feet radius. Their average weight in working condition is 57 tons, the whole being available for adhesion.

Mr. Clark (M. Inst. C.E.) in his paper on the locomotives in the International Exhibition of 1862, with regard to this type of engine, after referring to their top-heaviness and the overcrowded state of the tubes, says:—"The best thing about these engines is the uniform distribution of the weight, giving great tractive power without distressing the road on the straight portion; but the wheel base is impracticably long, and must greatly strain the engine and road, as well as add to the resistance on sharp curves. The proportion of the tractive power, taking the effective mean pressure in the cylinders at 80 per cent. of the boiler pressure for low speeds, is about one-sixth of the weight for adhesion, which is a fair proportion, and utilizes the immense weight of the engine."

There is another type of locomotive which is coming rather extensively into use on the continent (though it has not met with much encouragement in this country), and that is what is known by the name of the "bogie" type. They are very much to be recommended for sharp curves and steep gradients, and where the length of gradient is such as to warrant the expense of their construction. They are often as much as 60 tons in weight and generally have all their wheels coupled to the drivers.

I cannot well dismiss this part of my subject without saying a few words about a kind of engine which, no doubt, will quite revolutionize railway engineering. The invention, which is the subject of a patent taken out by Mr. Fell, Engineer, Sparkbridge, Lancashire, consists in obtaining additional adhesion other than that obtained by the weight of the locomotive itself. It is carried out in the following way:—Horizontal wheels in pairs are so arranged as to work on either side of a central rail by means of cylinders, and a steady and constant pressure is obtained between the wheels and rails by means of springs, though, of course, the pressure may also be produced by means of a steam cylinder, or even by water pressure. There is also an arrangement by which the pressure of the springs can be increased or dimished at pleasure.

In order to avoid friction in a vertical direction between the wheel and central rail, resulting from the movement of the engine on the springs which support it, vertical play is allowed. These wheels can also be used as brakes. The proposed immediate application of the invention, is to work locomotives and carriages on the steep inclines over the Alpine Pass at Mont Cenis and thus connect the French and Italian railway system ten years sooner than it could be accomplished by the completion of the great tunnel through the Alps, commenced some years ago by the French and Italian governments. For this purpose it is proposed to construct a railway on a portion of the existing public road between St. Michel in Savoy, and Susa, in Piedmont. The distance is about 48 miles, and the width sufficient to accommodate both the local and the railway traffic. Some of the gradients are upwards of 1 in 12, and the curves are generally very sharp. A locomotive on this principle has lately been tried on the Cromford and High Peak Railway. It drew a load of 20 tons, which is equivalent to 100 passengers and carriages, up an incline of 1 in 12, and round a curve of 2 chains, at an average rate of from 7½ to 12 miles per hour. The adhesive weight of the engine tried was 16 tons, and with the aid of the horizontal wheels it was increased to 32 tons; it was also found that the "grip" of the horizontal wheels was so firm, that with the addition of the brakes attached to the several carriages, the train was stopped on the incline.

Without stopping to discuss the merits of the various methods hitherto adopted for working steep inclines with sharp curves, I shall proceed to lay before you two plans I have to propose, and I ought to mention here that both of the projects under consideration were, as far as the general principles are concerned, the subject of a paper that I forwarded to the Institute of Civil Engineers, December, 1862, but as it only contained plans not executed or attempted, it therefore did not

come within the scope of its regulations, and, consequently, was not read at the meetings of the Institute.

A locomotive, having the propelling power within itself, advances by means of the adhesion between the touching points of the surface of the driving wheels and of the rails on which it is moving. This adhesion is only another term for the friction caused by gravity, or the weight of the locomotive pressing against the rails, by which, when the driving wheels are put in motion by the engine, an abutment, as it were, is presented to their motion *in situ*, necessarily causing them to advance, as the only motion they are susceptible of under the circumstances. But for the frictional resistance, produced by the weight of the locomotive between the particles of iron at the touching surfaces of the rails and wheels, the latter would merely revolve on their axes *in situ*, without any advancing motion.

Frictional resistance is experienced by all rolling bodies, and is obstructive of their motion, causing and representing a certain loss or expenditure of power in overcoming it. But in relation to the special action or function of the driving wheels of a locomotive, this resistance is beneficial, and necessary to the efficient application of the power in propelling the locomotive, and enabling it to draw whatever is attached to it.

The most favorable position for realizing the full effect of the surface adhesion between the rails and the driving wheels, is when the rails are perfectly horizontal, and the weight of the locomotive pressing in the line of gravity at right angles to the rails.

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## THE CAUSES OF THE FORMATION OF BARS AT THE MOUTHS OF RIVERS, AS SHOWN IN AN EXAMINATION OF THE CONNECTICUT RIVER.

By Gen. THEODORE G. ELLIS, C. E.

Transactions of the American Society of Civil Engineers.

The Connecticut River rises in the extreme northern part of New Hampshire, almost upon the border of Canada, and flows southward between the States of New Hampshire and Vermont, crossing the states of Massachusetts and Connecticut, and enters Long Island Sound.

In the States of New Hampshire and Vermont, its watershed is narrow and precipitous, and its tributaries are mostly small, partaking of the character of mountain torrents. In Massachusetts the drainage area is more extended, and streams of some size enter from the east and west. In Connecticut but one stream of any size enters the river. Below Hartford the tributaries are small, and, except in heavy rains, furnish but little water. All of the streams flowing into the Connecticut bring down more or less detritus in freshets.

From its source to the Massachusetts State line, the banks of the Connecticut are generally of a permanent character. Through the State of Massachusetts the river passes mostly through an alluvial formation, though in some places the bed is hard and permanent. From the town of Northampton to Hartford, and southward as far as Rocky Hill, the river flows through alluvial meadows overflowed in high freshets. In many places through this region the banks are washed away by the river. From about two miles above Hartford to nine miles below, the banks are generally a clay-loam upon the outside of the curves or bends, and upon the opposite side are low sand beaches, deposited by the river in freshets. The banks upon the outside of the bends are wearing away rapidly, generally caving off by being undermined, but in some cases the clay slides out from the bottom and rises up in the river, the top sinking down for 20 or 30 feet back to a level of 8 or 10 feet lower than before. The part that slides out soon washes away, and the operation is repeated. This part of the river furnishes a great amount of silt, and is continually changing its bed.

From Rocky Hill to the Narrows, below Middletown, the banks are more permanent and less subject to wash. At two or three

places, however, they are wearing away by the action of the water. Through the Narrows, for about a mile, the banks are high and rocky, and the channel deep and narrow. From this point to the mouth of the river the banks suffer but little abrasion from the action of the water, and are generally hilly, sloping downward to the water, and in many places rocky. The bed of the river, in the upper part, where it does not reach the rock, is coarse gravel; through the alluvial region it is generally a hard, fine sand, which becomes mixed with more or less mud in the lower part of the river near its mouth.

The Connecticut River is subject to freshets of considerable height, which mostly occur in the spring, when the river is swollen by the melting snow, although freshets have occurred in every month of the year, except June, July and September. The highest known freshet was in May, 1854, when the water rose to a height of 29 feet and 10 inches above low-water at Hartford.

The great height of the freshets at Hartford is due to the contraction of the waterway at the Narrows, just below Middletown. The river at this place is only 650 feet wide at the ordinary water-line, with steep and rocky banks rising to a great height on either side, so that the width probably does not exceed 800 feet at the highest water level. Through this gorge all the water must pass, which in freshets overflows the banks above and spreads out in some places nearly two miles in width over the meadows through which the river runs. The effect of this contraction is seen in the small fall in the surface of the water in floods between Hartford and Middletown. Middletown is about one-third of the distance from Hartford to the mouth of the river, and the average fall of water between these points in high freshets is only about one-sixth of the total fall. The distance from Hartford to Saybrook light is 49 miles.

The volume of water discharged by the Connecticut River is about 7.500 cubic feet per second at low stages of the water, and rises as high as 160.000 cubic feet per second in high freshets. The average discharge during the year 1871 was 19.388 cubic feet per second. The average velocity of the water varies from one to four miles per hour, according to the stage of the river.

During the spring freshets, the upper waters and tributaries of the Connecticut bring down large quantities of silt, which is deposited along its course, and upon Saybrook bar at its mouth. At high stages a large amount is deposited upon the meadows above Middletown, where the river spreads out to a great width, and the current is checked. Bars of sand are formed in the eddies, which wash away as the river falls. The finer particles held in suspension are carried forward by the current and deposited lower down or carried out over the bar at the mouth of the river. After the water has fallen, so as to be confined within its banks, through the alluvial region between Northampton and Rocky Hill, these banks are washed and carried off; furnishing a great amount of material to be deposited below.

At ordinary summer level, the tides affect the river to a point about seven miles above Hartford, the rise and fall at Hartford being about 10 inches; at Saybrook the mean rise and fall of the tides is 3½ feet. As the water rises the tides disappear. At 5 feet there is no tide at Hartford. In extremely low tides and a south wind, there is sometimes a reverse current as high up as Middletown. The slope of the river from Hartford to the sound, at ordinary summer level and mean tides, is about 2 feet. Above Hartford the slope becomes steeper and more irregular.

The foregoing details of the character of the river, although briefly stated, will give a sufficient idea of the nature and amount of detritus that may be expected to flow out at the mouth and be deposited in the sound.

In order to know what becomes of the material brought down by the river, it becomes necessary to investigate the currents and other natural causes affecting it after it leaves the river and enters the sound. The nature of the tides and tidal currents in Long Island Sound may be stated briefly as follows: The tidal wave from the ocean approaches the entrance to the sound from the southeast and flows into it, past Fisher's and Plum Islands, mostly through the middle part, called the Race. Another tidal wave enters the west end of the sound through New York Bay. These tides meet at some place between Sand's Point and Throg's Neck, according to the state of the tides. The wave passing up the sound from the Race is partly a wave of trans-

mission, with a progressive velocity depending upon the mean depth of the channel, and partly an actual flowing in and out of water through the Race. The crest of the wave of transmission moves from the Race to Sand's Point, a distance of 95 miles, in two hours. As the tide rises, the water pours through the Race at a maximum rate of about 5 miles an hour. This current opposite the mouth of the Connecticut River is about 2½ miles an hour. As the crest of the wave passes, the currents set back again in the opposite direction with about the same velocities.

As the tide rises in the sound, the currents set in towards the shore; and as it lowers they set outward from the shore, taking a direction slightly diagonal to the general direction of the central current.

At dead low-water the current from the river spreads out over the whole bar. The greater volume, however, follows the central or southeast channel. There are two other channels over the bar, one to the eastward, near the shore, and another to the southwest, with nearly as deep water as the central channel. When the rising tide commences to flow in from the southeast, it first dams back the river water and forms a distinct line of ripples along the outer edge of the bar. As the tide continues to rise, the stronger flow sets this ripple farther and farther on to the bar; turning back the current from the river, and throwing it farther to the westward, until what still flows out passes through the southwest channel.

From half-tide upward, a strong current sets in along the shore towards Griswold's Point, and flows across the mouth of the river, and partly into it, setting the fresh water back and raising the height of the water in the river. Just before the highest water, the current turns and sets strongly to the eastward along the shore, west from the light-house, impinging strongly upon the current flowing out from the river, and forming a well-defined ripple, extending southwest from the light. The great volume of water coming from the river, that has flowed into it on the rising tide, maintains its current southward until the tide has somewhat fallen, when the great volume of water sweeping down the sound overcomes the obstacle and pushes the river current over to the eastward, into and beyond the main central channel. This action of the littoral currents is evidently what forms the two side channels to the east and southwest.

Along the southwest edge of the bar, the outer bank is for a long distance very steep. This is probably caused by the strong wash of the ebb tide flowing along the shore from the westward, and striking upon the outer edge of the shoal.

A very complete survey of the mouth of the Connecticut River has been recently made by the writer, with a view to permanently improving the channel, which shows with great exactness the present form and state of the bar. By comparison of this with the maps of earlier surveys, we are enabled to determine the changes that have been going on, and study the causes which produce them. It will be unnecessary to go into all the details of changes which have occurred from time to time, as it would consume too much space, and prove uninteresting without having copies of the several maps to refer to. The principal changes only, and those having reference to the formation of the bar, will be noticed.

A comparison of the present survey with the United States Coast Survey Chart of 1853, and with a survey made in 1836, by Col. Julius W. Adams, will show the principal changes that have occurred during the past thirty-six years at and near the mouth of the river. Prior to September, 1815, as shown on Col. Adams's map, Griswold's Point extended much farther to the west than at present; reaching some 400 feet beyond what is now known as Poverty Island. To the north, between Griswold's Point and the foot of the island, was the channel of Blackhall River. In continuation of Griswold's Point, with a channel of about 200 feet between, was an island of above 2,300 feet long and 700 feet broad, of an oval form, extending out nearly to Griswold's north pier. The Blackhall River had two outlets, one on each side of the easterly end of the island.

In the gale which occurred in September, 1815, the whole of this island and the western portion of Griswold's Point, back to a long distance beyond its present limits were washed away. The ordinary action of the waves and currents again commenced to re-form the parts carried off, and, at the time of Col. Adams's survey, a point called Poverty Island beach had run out about 1,500 feet from the southwest corner of the large island now called Poverty

Island, upon the ground formerly occupied by the island washed away; and Griswold's Point had extended out to within 1,000 feet of its present limits. The mouth of Blackhall River was then just west of this point.

At the time of the coast survey, in 1850, Poverty Island beach had extended out still farther, and more to the north, to a length of 2,200 feet, and deeper water existed around it than before, Griswold's Point had also lengthened out about 600 feet. Poverty Island beach extended out some 200 feet farther, and was afterwards gradually washed away; being worn down by the action of the waves or river floods, and perhaps both; leaving at the present time but a small island of about 600 feet long, now known as Poverty Island Point. Griswold's Point has to the present time farther lengthened out about 500 feet.

The general outlines of the bar, as shown by the three surveys, are nearly the same. Although the outlines as shown by Col. Adams are not so extensive as those of the Coast Survey chart and the present survey, yet the two latter do not essentially differ, as to the extent of the bar, at the 18 feet contour line. There have been other minor changes, but none that affect the general character or the causes of formation of the bar.

It will be seen from the foregoing account of the principal changes at the mouth of the river, that great changes are constantly going on upon the eastern side, in the continual formation and occasional washing away of extensive spits and islands, while the western side remains always the same. The cause of this is to be found in the action of the waves during the continuance of the prevailing winds and storms. These are from the southeast, and the waves, acting diagonally along the shore, drive the material of which the beach is formed to the westward, until it meets the descending current of the river, which limits its farther motion in that direction. This wave action is constantly going on, and all the material carried forward eventually finds its way out upon the bar, either by being gradually transferred by the river current or by being washed out at once in a large quantity, as was the case when the island and point were carried off by the gale of September, 1815.

There is another important action of the waves besides that which transmits material along the shore; that is its action upon the outer edge of the bar. It is well known to all who have had occasion to examine the action of the sea upon an inclined shore, that it never carries off or swallows up anything. Everything is cast ashore or pushed out upon the beach, and the largest and heaviest things are thrown the farthest out and highest up upon the beach. This is caused by the progressive movement of the waves as they roll in upon the shore, and the same action occurs upon the outer edge of the bar to a depth equal to that of the same wave action upon the shore. The material of the bar is being constantly forced backward, up to a point where the river current is sufficiently strong to prevent its farther motion, and neutralize the action of the waves.

This wave action upon the bottom has been advanced as the sole cause of bars; the only conditions necessary being:

1st. The presence of sand or shingle, or other easily moved material.

2d. Water of a depth so limited that the waves, during storms, may act on the bottom.

3d. Such an exposure as shall allow of waves being generated of sufficient size to operate on the submerged material.

Where these conditions exist at the mouth of a river running into the sea or large lake of fresh water, a bar would undoubtedly exist, even though no sediment was discharged by the stream; but there are other causes which form bars, where one of the conditions above might not exist, viz., the limited depth of water before the commencement of the formation of the bar. In this case the action of the waves along the shore carrying sand or shingle into the mouth of the river, as it does in the Connecticut, would soon raise the height of the bottom so that it could be operated upon by the waves and raised into a bar, or the material might be supplied by suspended silt, or sand carried by the current along the bottom, which would be deposited in the dead water at the mouth of the river, and be formed into a bar in the same manner.

When a river brings down silt suspended in the water, a favorite theory has been to suppose that the bar is formed by the deposit of this silt when the fresh water meets the salt. The silt is supposed to remain suspended until the current is checked

by the fresh water expanding out over the surface of the underlying salt water, when it is deposited and is carried back by the under current of salt water as the tide enters the mouth of the river, thus forming the bar. The principal objection to this theory is, that bars are formed where streams enter fresh water lakes, and the supposed conditions do not exist.

Another theory of the formation of bars at the mouths of rivers, which has been advanced by the highest authority upon river hydraulics, is, that the sand and mud which is drifted along the bottom by the river current, passes into the sea until it meets the dead angle formed by the rising of the fresh river water over the salt water, when it is deposited and forms the bar. It is not explained what would be the effect of a river flowing into a fresh water lake, where all the water was of the same density; but for a stream flowing into salt water, this theory is amply sufficient to account for the formation of a bar. In the bar upon which observations were made to determine the cause of its formation by experiment, this was found to be the case.

I am led, however, to believe, from an examination of the Connecticut, and comparison with published records of other rivers and estuaries, that no single one of the theories named will account for the formation of all bars. In many cases a variety of causes are in operation to produce a bar and modify its form, either one of which might have produced it acting alone, but which all conduce to give it its existing form. In other cases fewer causes operate to create the bar, and may be different in different bars. In the Connecticut we have many forces in operation to give the bar its present form.

Its material appears to be largely composed of detritus brough down by the river in times of freshets, although some portion of it is washed from along the shore to the eastward by the action of the waves, and some may be swept across the mouth of the river by the littoral tidal currents of the sound. The silt brought down by the river during freshets, and the coarser material that is swept along the bottom are carried out and deposited upon the bar, where their character is modified by the action of the waves and by the tidal currents flowing in and out over the bar when the water in the river falls to its usual level, so that only the coarser part remains, the finer particles of silt being swept away. That part of the bar which remains nearly permanent, or subject to gradual and progressive changes, is mainly composed of coarse sand, much more difficult to move than the ordinary deposits which are formed in the lower portion of the river bed. The form of the outer edge of the bar is probably modified by the strong littoral tidal currents which flow back and forth in this part of the sound. The effect of the current from the westward, however, is more marked than that from the eastward, as it seems to limit the extension of the bar in a southwesterly direction by eroding its outer edge.

From the foregoing, and what has been previously said regarding the wave action along the beach to the eastward, and the action of the tidal currents in forming the side channels over the crest of the bar, it will be seen that we have the following general causes operating to create the bar at Saybrook and modify its form:

1. The suspended silt brought down by the river in freshets, which deposits upon the bar by the decrease of velocity in the stream.

2. The sand and coarse material which is swept along the bottom, and rolls out upon the bar until it meets the water of the sound.

3. The wave action which carries material along the beach towards Griswold's Point, to be in time carried out upon the bar by the river current.

4. The wave action affecting the outer slope of the bar to modify its form and drive back the material.

5. The littoral tidal currents flowing up and down the sound, and the current flowing in and out of the mouth of the river, which erode certain parts of the bar, and probably deposit material upon other parts, and otherwise shift and assort the material brought drown by the river, washing away the lighter particles, and thereby modify the general form and character of the bar.

The decrease of velocity in the river water named above may be either on account of the rising and spreading of the fresh water over the substratum of salt water, or over the crest of the bar itself; although the latter may be considered as a consequence of the bar rather than as an original cause of its formation.

At Saybrook there seems to be two

classes of causes operating conjointly to maintain the bar. One class furnishes the material, viz., the suspended silt, the sand washed along the bottom, and the material carried along the beach to the mouth of the river by the wave action. The other class retains the materials upon the bar, viz., the rising of the fresh water over the salt, and forming a dead angle, the spreading out of the water over the bar already formed, and consequent checking of the velocity, and the wave action upon the outer slope of the bar.

It is not presumed that all of the above causes operate upon every bar; one of each class, acting together, would undoubtedly create and maintain a bar. They are named to show that all bars may not be produced by the same causes, nor be accounted for by the same general simple theory. Examples of the formation of bars from different causes may be seen in the deposits at the mouths of the river Wear, at Sunderland, England, and of the Dornoch Firth, in the north of Scotland; which are almost entirely due to the wave action of the sea; and in the vast accumulations at the mouth of the Mississippi and Danube, which are wholly formed of detritus brought down by those rivers. The bar at the mouth of the Wear is shown by dredgings to be formed of the same material as the adjacent beaches, viz., sharp, gritty sand, brickbats, chalk, flint, pebbles, and marly rock; materials which could not by any possibility have come from the river. The bar at the mouth of the Dornoch Firth is fourteen miles to seaward of where the fresh water joins the salt, and is composed of a sharp sand, while the small rivers which discharge into the firth bring down very little silt, and that is of an alluvial character. The material of which the bar is formed is evidently washed from along the shore by the progressive action of the waves from the north sea, with its inner slope modified by the currents from the firth, and its outer slope by the wave actiod throwing it back. The bar at the mouth of the Mississippi is, without doubt, wholly formed of the sand and mud carried by the current along the bottom, and deposited in the dead angle between the fresh and salt water, as has been described; and the same may be said of the Danube, except that the immense amount of suspended silt brought down by that river into the tideless Black Sea has, perhaps, a more important part in the formation of the bar than the suspended material of the Mississippi, which is carried farther out to sea.

I think the wave action upon the outer slope of bars at the outlets of rivers has a greater effect in modifying their form than is generally supposed. An examination of the outer slope of such bars shows an inclination about that assumed by a beach of the same materials to a certain depth, which is generally that to which the water is affected by waves. The slope then makes an angle, and becomes much flatter. This flatter portion is probably below the influence of the waves, and the sediment lies where it is deposited. This is seen in the form of the Saybrook bar, where there is a flat portion at about 12 feet in depth; in the Mississippi bar, where it is about 100 feet in depth, and also in the sections of other bars of which surveys have been made. The steeper part of the slope just over the crest is evidently not formed in the same manner as the steep lower side of river bars, lying above where they are affected by the tide, in which the slope is formed by the particles of sand which have been rolled to the crest by the current, and drop down the lower side by their gravity. The slope is too flat for this idea to be entertained.

The littoral currents of the ocean also tend to modify the form of bars, as is seen in the Connecticut by the erosion of the southwestern edge of the bar, and in the form of the channels across the crest. These currents also carry off the finer portions of the sediment and deposit it in other localities.

About a mile to the southwest of the extreme point of Saybrook bar, a long sand shoal commences, and stretches westward for about six miles, averaging at the 18 feet depth about one-quarter of a mile in width. The material which forms this shoal probably comes from Saybrook bar, and is carried along by the incoming tidal current, while the outgoing tide keeps the channel open between it and the shore. The exact method of formation of this shoal, however, has not been investigated, and it may be due to other causes than those named. Its form and character are taken from the coast survey charts, and it cannot be seen to have any effect upon the form of the bar proper, although it is probably derived from it. On account of its distance, and the deep water between, it

cannot properly be considered a part of the bar.

It is proposed during the coming season to commence some permanent works for improving the channel over the Saybrook bar. Some new ideas are believed to be advanced in the improvements contemplated, by taking advantage of the littoral currents to maintain the channel; but no description of them will be attempted at the present time. It is thought they will be successful, and, if so, they will be described at some future time.

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## RUSSIA, HER INDUSTRIES, COMMERCE, AND MEANS OF COMMUNICATION.

By LEONE LEVI, Esq.

Journal of the "Society of Arts."

The holding of another session of the International Statistical Congress called me to St. Petersburg this year. We met on former occasions at Brussels, Paris, London, Vienna, Berlin, Florence, and the Hague, and everywhere we were received by the Government of the country with great honor and hearty hospitality. The Russian government offered every facility for our journey, and I accepted the invitation to the Congress, and attended it as one of the deputies for the Statistical Society. As for the choice of route, it practically rested between a sea route by Sweden, and a land route, either by Kœnigsberg and Eydkuhnen, or by Berlin and Warsaw. I decided to go by the land route *via* Warsaw, and to return by Stockholm, Copenhagen and Hamburg, and on Saturday, August 10, I, accompanied by my good wife and two dear friends, went from London, *via* Harwich, to Rotterdam—by an excellent boat, it may be, but with more on board than she was fit to carry with comfort; from Rotterdam to Utrecht; thence to Hanover and Berlin, and from Berlin by Bromberg to Warsaw. Utrecht is a quiet and handsome town, Dutch in character, and beautifully clean. At Hanover I saw the effects of the change of dynasty; and Berlin, since I last visited it, has become an imperial city, richer than ever in museums and monuments, but too many, alas! devoted to military heroes.

Warsaw, the ancient capital of Poland, I was glad to see, though I could not help feeling regret for the down-trodden city, where Kosciusko fought with so much valor for the liberty of his country. Yes, there she was, on the banks of the Vistula, with her palaces turned into barracks, and her monuments diverted from their intended purposes. But there is life in Warsaw, and there is a good deal of trade and industry. In 1869 the exports and imports of Poland amounted to about £17,000,000, the exports consisting principally of rye, wheat, timber, flax, and bristles. The railway has rendered Warsaw the best point of transit between Austria, Prussia, and Russia. From Warsaw our route was due north, almost a straight line to St. Petersburg, about seven hundred miles in length, and thus we had ample opportunities of seeing a considerable portion of Russian territory. But how different from the usual English scenery! For miles and miles scarcely anything interesting attracted our notice. Before us was an interminable plain, not a hill to be seen, not even a valley. Surely nature is capricious in her gifts. Go to Italy, Switzerland, or Scotland, and you find the towering mountain, the precipitous rock, the fearful torrent, land and water defying by their grandeur and sublimity the ability of the greatest artist to reproduce by the pencil or the chisel. Go to Russia, and travelling seems monotonous to a degree; but do not think that Russia is so uniformly flat. The Ural mountains, which form a natural frontier between European and Asiatic Russia, the Caucacus mountains also separating Europe from Asia, in the the south, the Carpathian mountains in Bessarabia, and the hills of Finland, are all of considerable height.

What we noted on the road was the poor aspect of the agriculture, the sandy soil, the stunted trees, the rarity of farmhouses, and the almost total absence of sheep. How barren everything looked! For agricultural purposes Russia has been divided into seven distinct regions. The northern region, from the Gulf of Bothnia, to the

northern part of the Oural mountains, including Finland, Archangel, Wologda, and Olonetz, have very little of tillage land. The region of the Alaounes heights, or the plateau which separates the basins of the Dnieper and the Volga, is mostly forest land. The tillage land is not very fruitful, the meadow land scanty. The Baltic region, including Livonia, Courland, and Esthonia, is not very fertile, though somewhat better cultivated. The lower region, including some of the provinces through which we passed, has a very poor soil, and is principally forest land. The Carpathian region, embracing Ukraine and Little Russia, is the most fertile part of the empire. There is the region of the Steppes, including Bessarabia, Kherson, and Astrakhan—a land without trees, seldom watered by refreshing rain, yet eminent as pasture land. The central region, comprising Kostroma, Moscow, Nijni, and Wladimir, is rich in cereals. And the Oural region, including all the eastern part of European Russia, has a soil generally fertile. To show the difference between other regions and the one over which we passed, while Tula, Kursk, Vorones, Tambov, and Kief, have from 60 to 70 per cent. of tillage land, the provinces on our way have at most 40 to 50 per cent. If, then, we did not see any rich soil, or any well cultivated land, they do nevertheless exist in Russia. Does not Russia supply us yearly with large quantities of grain? In 1861 only 12 per cent. of our imports of grain came from Russia; in 1871, the proportion was 35 per cent. In 1861 the total imports were 37,646,000 cwt., and from Russia 4,540,000 cwt.; in 1871 the total imports were 44,362,000, and from Russia, 15,670,000 cwt. The meadow lands of Russia are principally in Finland and Archangel in the north, and in the Don Cossacks and Caucasian provinces in the south. In these provinces Russia has a large stock of some 25,000,000 head of cattle, and 45,000,000 sheep. As for horses, the great centre of horse-breeding seems to be at the very border of the Oural mountains. Russia is stated to have 18,500,000 horses, when the United Kingdom has only 2,600,000. The great difficulties which hitherto have hindered the agricultural progress of Russia have been serf labor, want of capital, want of intelligence, bad roads, and great distances. Now serfdom, in principle at least, is abolished, and the railways are providing new means of access to far distant provinces. May we not hope that with these, capital and intelligence may also find their way thither, and that together they may tend toward the development of resources far exceeding our present expectation? It has been calculated that, while Belgium and the Netherlands produce 14 hectolitres of corn to every hectare of arable land, and England 13 hectolitres, Russia produces only 6 hectolitres. What if, by the means indicated, the productiveness of land could be doubled? With her immense area Russia might replenish the granaries of Europe with the greatest ease.

But fancy travelling in the interior of Russia in sumptuous railway carriages—how different as compared with the time when Richard Chancellor accidentally got into the Bay of San Nicholas, on the White Sea, landed near Archangel, then only a castle, and travelled on sledges to the Czar at Moscow! The first-class railway carriage in Russia is really luxurious. It is a saloon, with all the necessaries, and some of the elegancies, of such an apartment. It is furnished with looking-glasses, heated by porcelain stoves, and lit by lamps and candles. Along the sides soft divans are ranged, which, by a simple process, are turned into beds. But they are in no hurry in Russia; while here we travel at the rate of 30 to 40 miles an hour, there the ordinary rate is from 15 to 20 miles an hour. From St. Petersburg to Moscow, 430 miles, we employed 17 hours. The fares in the Russian railways are lower, of course, than in this country. The average fares on the five principal lines are as follows:

| — | Copecs per Verst. | | | Pence per Eng. mile. | | |
|---|---|---|---|---|---|---|
| | 1st Class | 2d Class | 3d Class | 1st Class | 2d Class | 3d Class |
| St. Petersburg to Moscow | 3.10 | 2.11 | 0.77 | 1.40 | 0.95 | 0.34 |
| St. Petersburg to Warsaw | 2.96 | 2.20 | 0.92 | 1.33 | 1.00 | 0·46 |
| Moscow to Nijni. | 4.9 | 2.27 | 1.13 | 1.33 | 1.00 | 0.51 |
| Riga to Nunaburg | 4.08 | 2.59 | 1.73 | 1.96 | 1.22 | 0.77 |
| Odessa | 2.95 | 2.21 | 1.06 | 1.33 | 1.00 | 0.46 |

The division of classes in the Russian railways is much more distinct than in the English railways. The third-class passengers are mostly peasants, clad in the most miserable manner, and many with visages almost forbidding. The stations are commodious, and the buffets well-furnished, nor are the prices so extravagantly high as is often represented. On the whole, Rus-

sia is in a fair way of being largely intersected by railways. On the 1st of September, 1871, there were in Russia 11,138 versts, equal to 7,351 miles of railway, and the capital employed in them was 918,000,000 roubles, equal to £122,000,000. In the United Kingdom the capital so invested in 1870 was £530,000,000. The number of passengers carried in Russia was only 12,000,000, against 330,000,000 in this country. Most of the Russian lines have a government guarantee of from 4½ to 5½ per cent. interest, and the actual dividends paid on the shares amounted in 1870 to from 5 to 7½ per cent. Two lines only seem eminently profitable, viz.: the Moscow-Riazan line, which gave 17½ per cent., and the Koursk-Kiew line, which gave 31¼ per cent. The concession to the companies is generally for from 70 to 80 years. Very few lines now belong to the State. To Russia the railways are of the greatest possible advantage. From Moscow, the central *reseau*, you may now travel east as far as the Oural mountains, north to St. Petersburg, west to Kœnigsberg, and Warsaw, and south to Odessa, Sevastopol, and Astrakhan. And it is even contemplated eventually to extend the railway across the Oural mountains, through Siberia, to China. Yet I doubt whether railway property will be profitable in Russia for many years to come, whatever be the ultimate result. The mass of the population in Russia are too poor to travel —they are not accustomed to it; the passport system interferes with it. There is nothing, moreover, to feed the lines midway, so few are the centres of population and traffic. And Russian produce consists mostly of grain and other bulky articles, which can not stand much freight, and can as well be transported by water communication. It should be remembered that excellent means of communication exist in Russia in her enormous rivers and lakes. The Vistula, at Warsaw, looked beautiful, and the Volga, which we passed near Moscow, is more than ten times the length of the Thames. There is a canal communication, moreover, between St. Petersburg and the Caspian Sea, between the Baltic and the Black Sea, and between the White Sea and the Caspian. Only it is unfortunate that all the canals, lakes, and rivers, aye, even the seas of Russia, are closed by the ice for about seven months in the year. How important, then, to extend the railway system into the very heart of the country. In winter the railway must of necessity monopolize the whole traffic of the country.

It was a long way between Warsaw and St. Petersburg, requiring at least thirty hours of constant journeying, so we determined to rest at Wilna, the chief town of the ancient Duchy of Lithuania; but how poor did she seem to be! Wilna is well situated in the hollow at the foot of several hills, and contains many objects of interest; but, as a rule, the towns and villages of Russia are poor and badly built. The houses are mostly of wood; the streets wretchedly paved. In many cases, moreover, the towns are not the spontaneous result of trade and industry, but the capricious plantations of administrators or military officers. The only towns of any importance in Russia are St. Petersburg, Moscow, Warsaw, Odessa, and Riga. In 1867 the entire population of the Russian Empire was not less than 82,000,000, and of this probably less than 5,000,000 was urban population. But why should St. Petersburg be the capital of Russia? Some cities have become capitals from the fact that the sovereign from time immemorial resided in them. Some owe their position to their favorable situation, and some to the fact of their containing the largest number of persons. St. Petersburg can claim neither of these titles. She is at the very extremity of the empire; she has none of the prestige which Moscow possesses, and she has but a small proportion of the population of the kingdom. While London has about 100 persons to every 1,000 of the population of the kingdom; Lisbon, 61; Copenhagen, 59; Athens, 55; Dresden, 55; Paris, 45; Berlin, 27; Constantinople, 22; Vienna, 14; St. Petersburg has only 7 to the 1,000. St. Petersburg is the capital of Russia simply because Peter the Great willed it; but a force greater than that of the emperor points to Moscow as the natural centre. But St. Petersburg is doubtless a beautiful city. As we entered the station in St. Petersburg an officer from the Congress communicated to us that the municipality offered to us its hospitality; that hotels had been provided for the convenience of members, and carriages placed at our disposal, so we drove at once to the Hotel Bellevue, on the Newski Prospect. And what a sight was before us in that street, more than three miles in length, full of bustle and animation. As a city St. Petersburg stands in favorable comparison

with Berlin for life and cheerfulness. The magnificent Neva, which winds through the town, is infinitely superior to old Father Thames, though no forest of masts meet you at any of the quays. A pure sky and a dry atmosphere are preferable to our everlasting damp and fog. The low drowskies, with Ivan ever at hand, carry you over the otherwise tumble-down pavement with the greatest celerity. Something out of the common-place civilization of Paris and London meets you at every corner.

It was the 21st of August when we arrived at St. Petersburg, where we found the temperature warm and genial. The thermometer was from 65 to 70 in the shade, and otherwise the climate was clear and dry; yet now and then we felt extremely cold; and I understand that, owing to such variations, the climate is very trying to health. Hence the general habit of wearing long heavy coats and closed up dresses at all times; hence the hermetically shut up windows and doors in the warmest days. But I have not seen St. Petersburg in winter, when the Neva is frozen, when snow and ice take possession of her streets for months together, when the drowsky is replaced by the sledge; when the fur clothing, the fur collar and sable hat, constitutes the costume of ladies and gentlemen. The temperature in Russia is regulated more by the longitude than by the latitude. The more eastward we go the greater is the difference between the temperature of summer and winter.

In matters of food and drink we had little difficulty. Our first care was to eschew altogether the water of the Neva, which, containing a certain quantity of magnesia, generally proves relaxing, especially to strangers. But, otherwise, no better food could be had than was supplied to us at the principal hotels. Our rouble dinner at the Bellevue was superior to any three-shilling dinner in London, and the wine was excellent. At a dinner at Moscow we had different descriptions of Russian wines, principally from the Crimea, and they were much appreciated. Mr. Beckwith, in his excellent report on fermented drinks at the Paris exhibition, said that the white wines of the Crimea are clear and dry, with a slight muscatel flavor and good body; and the red resembles very old port, bereft, however, of its strength. In Mr. Beckwith's opinion these wines are very suitable to our climate. M. Tegobonski gave the production of wine at about 42,000,000 gallons, of which 8,000,000 come from the province of Stravropol, 8,000,000 in Bessarabia, 22,000,000 gallons in the Trans-Caucasian provinces, and the rest in the Crimea, the Cossacks, Khenan, Podolia, and Astrakhan. In Russia, Germany, and other northern countries, the people generally eat black rye bread—very uninviting, but remember that, with the dryness of the climate, a portion of black bread, and other elements containing vegetable acids, are absolutely necessary to prevent scrofula, more especially among young people.

But we must regard Russia this evening from an industrial and not from an æsthetic aspect, and in so doing we must guard ourselves from considering the industries of Russia as limited entirely to the urban population. On the contrary, there are villages in Russia in which all the peasants are weavers, tanners, shoemakers, locksmiths, cutlers, &c. In Russia the peasant works for the manufacturer without quitting the village, and carries on himself the chief part of the commerce of the interior. I was informed that there is no peasantry more hard working than the Russian peasantry, and that the women are constantly employed not only in household duties, but in agricultural work, in weaving, bleaching, and many things which in England are done by machinery in factories and in manufacturing towns. Primarily, no doubt, Russia in an agricultural and not a manufacturing country. But, after all, agriculture is the greatest source of wealth to any country. England is by far the most industrious and the most mercantile country in the world. She supplies the whole world with her manufactures. She has the largest mercantile marine. Her power rests on her commerce and industry. Yet, with all this, the results of the income-tax show that the income of all her industry is only about equal to her income from her agriculture and real property. Still greater is the supremacy of agriculture in Russia. In truth, Russia is wanting in some of the principal conditions for industrial prosperity.

Look at the map of Russia. She has no sea-coast of any importance. On the far east there are the vast plains of Siberia. On the west she has Eastern Prussia, quite as deserted and agricultural as Russia herself. On the north she has the glacial Pole; on the south none but semi-barbarous states.

Add to this a population almost entirely composed of peasants; no coals in any quantity, or, at any rate, scarcely worked at all; very little capital; and every agent of manufacture extremely dear. What chance can Russia have in commerce and industry in competition with these sea-girt isles, or with well-favored France or Italy? A mill in Russia costs double that of a mill in England. Bricks are dearer and double the quantity is used to render the building substantial; mortar costs double, and so does all machinery. Consequently, but little factory labor is introduced into Russia. What there is, moreover, is to a large extent under the direction of Englishmen, Germans, Alsatians and other foreigners. British directors and overseers manage the best factories. In the south of Russia it is the same. Vice-Consul Stevens, of Nicolaieff, reported that the chief ganger at the granite quarries at Alexandrovka is an Englishman; the director of the extensive Tchemornski sugar factory in Pattawa is the same; so are the superintending engineer of the Russian Steam Navigation Company at Odessa and his assistant; and the company's chief engineer in the Don mines; the one at Sevastopol; their boiler-master, their master-painter, and the heads of other departments are also Englishmen. The English, the French, the Germans, and the Greeks have a large share in the direction of Russian trade and industry. The Russian mind wants in power and in originality. It is better able to execute, than to direct—to imitate, rather than to lead. I visited a cotton printing factory in Moscow directed by an Alsatian, and I found that the laborers were Russian peasants who come from the country when agricultural labor is impracticable, to recruit the earnings of the family. Such peasants are usually hired in gangs, the head of which assumes the management of the expenditure of the whole number. They live, I need not say, at very small cost, and at any time labor ceases in towns, they return to the country. There are not in Russia as in this country, millions of mechanics, spinners, or miners depending for their livelihood on the buoyancy of trade and manufacture. There is rather an intermingling of agricultural and industrial labor, and consequently an utter absence of the artisan class, the precarious existence of which we have so often to lament in this country.

But let us enter into some details. The first article of industry which naturally interests this country is cotton. Cotton is not produced in Russia, and her imports of 1867 consisted of about 2,600,000 poods, or about 100,000,000lbs. of raw cotton, and 150,000 poods of cotton yarn. Mr. Lumley, in his report of the trade and manufacture of cotton in Russia, gave the number of cotton spinning and calico weaving manufactories in the government of St. Petersburg in 1862, at 95, with 1,691,224 spindles, 16,141 power looms, and 8,040 horse power; and Mr. Michel, in his valuable report on the Russian tariff, told us that the whole quantity of cotton yarn manufactured in Russia is used as follows:—1,400,000 poods for printed calico, 200,000 poods for nankeen, red fustian, and Turkey red goods; 100,000 poods for plush, and the remaining 500,000 poods for various other cotton and half-cotton fabrics. Russian spinneries supply the weaving mills with yarn of low and medium quality; foreign yarn is alone employed for cotton tissue of superior description, such as fine calico, jaconet and muslin. The manufacture of the common kinds of cotton fabrics, namely, calico, nankeen, red fustian, and handkerchiefs, intended chiefly for dyeing and printing, forms a branch of peasant industry, supported by the capital of manufacturers in towns and particularly by that of the owners of print-works. The consumption of cotton goods in Russia must be large. Supposing 60,000,000 peasants to consume 10 archines, or about 8 yards each, that would give about 480,000,000 yards. Add to this the consumption of 5,000,000 urban population at 20 archines each, or 15 yards each, 75,000,000 yards more, and we have a total of upwards of 550,000,000 yards. Yet, in the face of all this, all our exports of cotton to Russia in 1871 consisted only of 3,477 lbs. yarn, and 140,000 yards of goods of mixed materials in which cotton predominated. Why do we not supply Russia more largely with our staple manufacture? Partly in consequence of a very high tariff, and partly also from want of adaptation of British goods to the tastes and habits of the many races and nationalities residing in Russia. The tariff was somewhat reduced in 1868, the duties on cotton yarn from 16 to 20 per cent., and the duties on cotton manufactures from 22 to 27 per cent.; but still the present duties on the latter, of from £5 10s. to £23 12s. 11d. per cwt., must be

considered as practically prohibitive. I shall not weary you with any description of the condition of other industries—of woollen, flax (on which I wished to make mention of Dr. Collier's new treatment), of leather, tallow, and metals—because, in reality, they are more or less governed by the same general circumstances.

Mr. Michel gives the following summary of Russian manufacturing industry:—

| Nature of industry. | No. of works and mnf'tories | Number of workmen. | Value of production in roubles. |
|---|---|---|---|
| Cotton | 606 | 69,347 | 71,725,459 |
| Hemp and flax | 225 | 22,259 | 11,405,686 |
| Woollen | 614 | 92,322 | 22,565,518 |
| Silk | 293 | 7,933 | 4,488,421 |
| Dye Works | 204 | 3,919 | 4,196,603 |
| Paper | 170 | 13,203 | 5,275,816 |
| Leather | 2,471 | 13,245 | 18,164,897 |
| Tallow | 1,595 | 10,566 | 22,553,225 |
| Wax | 216 | 1,083 | 2,722,624 |
| Pottery | 289 | 4,178 | 1,321,078 |
| Glass | 210 | 10,744 | 4,402,774 |
| Metals | 713 | 47,379 | 28,688,124 |
| Chemicals | 377 | 6,136 | 23,195,817 |
| | 7,982 | 302,314 | 230,654,072 * |

Distillation of 27,000,000 vedros of pure spirits, equal to about 73,000,000 gallons.
Beer and mead brewed, 7,900,000 vedros, equal to about 21,000,000 gallons.
Beet-root sugar produced, 3,300,000 poods.
Tobacco manufactured, 594,000 poods.
Iron raised, 15,781,000 poods.

One important element should not be omitted in any review of Russian industry. It is the possibility that ere long considerable quantities of coal may be obtained in different parts of the country. In the Don district the increase has been remarkable:

| | | | | |
|---|---|---|---|---|
| In 1820 | there | were | produced, | 350 |
| 1840 | " | " | " | 800,000 |
| 1847 | " | " | " | 2,860,000 |
| 1863 | " | " | " | 6,350,000 |

The Moscow Exhibition gave evidence of the existence of coal in considerable quantity.

For the commerce of Russia St. Petersburg is by far the most important outpost, though Moscow is the centre of Russian industry. In both places there is evidence that the general movement of trade is extending rapidly. In 1859 the entire value of imports and exports amounted to 329,000,000 roubles. In 1869 it reached 592,000,000 roubles. Among the exports, grain, hemp, and flax are by far the most important. Among the imports, cotton and metals stand foremost. An important change is observable in the foreign commerce of Russia, in consequence of the extension of railways. In 1859 the foreign exports by sea amounted to 130,000,000 roubles, and by land, to 22,000,000 roubles, or about 16 per cent. In 1869 the exports by sea amounted to 190,000,000, and by land 95,000,000, or 50 per cent. While bulky goods are sent by sea, lighter goods penetrate by land, chiefly from Prussia and through the Prussian frontier. It should be noted here that, while the commerce of Russia with European States has largely increased, her commerce with Asia has actually decreased of late. The Asiatic portion of the Russian trade is small as compared with the European, and yet considerable interest attaches to it, first on account of the primitive manner in which it is still conducted, and secondly, in consequence of the intimate relation which exists between the extension of trade and the constant enlargement of the Russian empire. By incorporating Turkestan, Russia has come very near British India, and now she has commercial treaties with the Khan of Khokand and the Ameer of Bokhara and Dschiti Tchar. But what does it matter by what influence it is brought about, provided these States are rendered accessible to trade and civilization?

Being in a certain sense the guests of the Emperor of all the Russias and of his august government, we were honored with numerous invitations to receptions and excursions. One day we went to Cronstadt and Peterhoff. Another day we had a sail round the islands, and were entertained in one of the palaces of the Princess Helena, which at night was beautifully illuminated. What we most appreciated in these receptions was not so much the sumptuousness of the entertainments, as the consideration shown in making us what the English think they alone understand, but what other nations know quite as well—I mean "comfortable." To put us at ease—to anticipate our wants—to endeavor to speak our language—to put every individual and every thing in the right place, that is the perfection of hospitality.

The grandest excursion of all, however, was to Moscow, whose municipality was as courteous as that of St. Petersburg in supplying members of Congress with hotel accommodation and carriages during their stay in the city. At first sight Moscow is by no means attractive. It seems an old city, badly paved, and with irregular buildings. But from such a height as the Sparrow

* Equal to about £30,000,000.

hill—the very ground whence Napoleon obtained his first glance of Moscow—the sight of the golden minarets and starry domes before you is quite unique and startling. According to arrangement, we visited the Polytechnic Exhibition at Moscow, an excellent one of its kind. I was not able to inspect it with any care or minuteness, especially as we visited the exhibition in great numbers, but it was apparent, first that Russian industry is by no means in such a backward state as is generally supposed; and, second, that British industry was most imperfectly represented. The exhibition—consisting of a number of pavilions alongside the garden of the Kremlin—did not seem to have much unity, while it was altogether destitute of a general *coup-d'œil;* yet it possessed many objects of great interest and attraction, and day by day we saw it visited by large numbers of people.

At Moscow, as well as at St. Petersburg, but more especially in the latter place, I found British merchants of the highest respectability, numbering in all probably some 3,000, the living representatives, I suppose, of the Russia Company with its agency at St. Petersburg, under the title of the British factory, founded by charter of Philip and Mary, about 300 years ago. The original charter confirmed by Act of Parliament granted that, "All the main lands, isles, ports, havens, creeks, and rivers of the mighty Emperor of all Russia and Great Duke of Musky, &c., and all and singular other lands dominions, territories, isles, ports, havens, creeks, rivers, arms of the sea, and all and every other prince, ruler, or governor whatsoever, be or they be before the said late adventure or enterprise not known, or by the foresaid merchants and subjects of the said King and Queen by the seas not commonly frequented, nor any part or parcel thereof, and lying northward, northeastward, or northwestward, or in the said letters patent is mentioned, should not be visited, frequented, nor haunted by any of the subjects of the late King and Queen other than of the said company and fellowship and their successors, without express license, agreement, and consent of the governors, consuls, assistants of the said fellowships and commonalty." That no such permission is now required to trade in Russia is well known, yet, singular to say, charges are still made by the Russia factory on British shipping using the port of St. Petersburg or Cronstadt, being first a charge of 3½d. per ton for the maintenance of the British Episcopal Establishment at that place and in aid of the poor's fund, and, second, a charge under the head of Company's Agent, which amounts to $1\frac{1}{10}$d. per ton. A few years ago some effort was made by the Hull Chamber of Commerce to procure the abolition of these charges, when it appeared that the tonnage duty, denominated church money, amounted, on an average, to only £2,200 per annum, and the agent's only to £956. But the charge, though light, is not less condemnable. The British factory has, in reality, long ceased to exist or to be needful; and I imagine that the British merchants in St. Petersburg, or such of them as are Episcopalians, should themselves pay for the church, and that the British government should pay for the agency, without taxing trade and shipping for such purposes. Generally, I need scarcely say, English merchants in Russia are as safe and protected as if they were in England. It should be remembered that the government of Russia now is not the arbitrary government that it was in former days. True, the Czar is autocrat absolute, but he does not act alone, and far less capriciously. He has a council of responsible ministers; he has a House of Lords, of his own creation, doubtless, but yet able and willing to render him advice; he has a holy synod, and he has governors in every province, able to feel the pulse of public opinion, and with full power to meet the exigencies of the moment. And do not think that public opinion does not find itself vent in Russia. There are newspapers in Russia, though much under the power of the State. The silent protest under wrongs, the murmurs of the oppressed, the aspirations of the enlightened, can not be smothered even in Russia. But in truth Russia is tranquil at this moment, and the Emperor has the heart of the people with him. Nowhere did I see any parade of military force, as we are wont to see in turbulent Paris or in imperial Berlin. As for the people, it is, I fear, as yet in a low condition. The mass of the peasantry recently emancipated has scarcely risen from the position of serfdom. The industrial classes are ill-paid, ill-fed, and in the depth of ignorance. The middle classes scarcely exist in Russia. The nobles do not exercise much wholesome influence. The priests hold an inferior position to what we are accustomed to in this country. Something is, however, done for the

education of the people. There are nine universities, three lyceums, 23,000 schools, and nearly 1,000,000 students in the public schools in Russia. The freedom of serfdom is a most significant fact, the fruit of which will one day appear. What may be the future of the Russian people, when free and educated, we cannot say. Meanwhile, trade is increasing, the country is progressing, and the railway opens up the country in a wonderful manner. As far as I can see, I venture to say the Russia of the future will be far different in power and enlightenment, in commerce and industry, from the Russia of the past.

Ere I close, permit me to express my own sense and the sense of every foreign member of the International Statistical Congress, of the kindness shown us by the Russian government on the occasion of our visit to Russia. Would that England received in like manner men of science from other countries when they come to her soil. It would be well if her example were more conspicuous for a liberal expenditure than for a niggard economy in all matters which concern the promotion of science and art. Would that the same coöperation on the part of the officers of State could be secured for the meeting of scientific congresses in London as is so readily obtained in other countries. Perhaps it may not be in vain that her messengers to Russia, to Italy, to Holland, and to every state where the International Statistical Congress has been held, are able to report that a reception the most courteous, the most hospitable, the most considerate, is everywhere accorded to men of science when they meet together for the elucidation of great questions, either of social economy or of scientific importance.

## THE ORIGIN OF METALLIFEROUS DEPOSITS.

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From the transactions of the American Institute of Mining Engineers.

There are about sixty bodies which chemists call elements; the simplest forms of matter which they have been able to extract from the rocky crust of our earth, its waters and its atmosphere. These substances are distributed in very unequal quantities, and in very different manners. As regards the frequency of these elements in nature, neglecting for the present those which constitute air and water, and confining ourselves to the solid matters of the earth's crust, there are a few which are exceedingly abundant, making up nine-tenths if not ninety-five hundredths, of the rocks so far as known to us. The elements of which silica, alumina, lime, magnesia, potash and soda are oxides, are very common, and occur almost everywhere. There are others which are much rarer, being found in comparatively small quantities. Many of these rarer elements, are, however, of great importance in the economy of nature. Such are the common metals and other substances used in the arts, which occur in nature in quantities relatively very minute, but which have been collected by various agencies, and thus made available for the wants of man. It is chiefly of the well-known metals, iron, copper, silver and gold, that I propose to speak to-night; but there are two other elements not classed among the metals, which I shall notice for the reason that their history is extremely important, and will, moreover, enable us to comprehend more clearly some points in that of the metals themselves. I speak of phosphorus and iodine.

You all know the essential part which the former of these, combined as phosphate of lime, plays in the animal economy, in the formation of bones; and how plants require for their proper growth and development a certain amount of phosphorus. Ordinary soils contain only a few thousandths of this element, yet there are agencies at work in nature which gather this diffused phosphorus together in beds of mineral phosphates and in veins of crystalline apatite, which are now sought to enrich impoverished soils. Iodine, an element of great value in medicine and in the art of photography, is widely distributed, but still rarer than phosphorus, yet it abounds in certain mineral waters, and is, moreover, accumulated in marine plants. These extract it from the waters of the sea, where iodine exists in such minute quantities as almost to elude our chemical tests.

There are probably no perfect separations in nature. We cannot, without great precautions, get any chemical element in a state of absolute purity, and we have reason to believe that even the rarest elements are everywhere diffused in infinitesimal quantities. The spectroscope, which we have lately learned to apply to the investigation alike of the chemistry of our own earth and that of other worlds once supposed to be beyond the chemist's ken, not only demonstrates the very wide diffusion of various chemical elements here on earth, but shows us that very many of them exist in the sun. If we accept, as most of us are inclined to do, the nebular hypothesis, and admit that our earth was once, like the sun of to-day, an intensely heated vaporous mass; that it is, in fact, a cooled and condensed portion of that once great nebula of which the sun is also a part, we might expect to find all the elements now discovered in the sun distributed throughout this consolidated globe. We may speculate about the condensation of some of these before others, and their consequent accumulation in the inner parts of the earth, but the fact that we have all the elements of the solar envelope (together with many more) in the exterior portions of our planet, shows that there was, at least, but a very partial concentration and separation of these elements during the period of cooling and condensation. The superficial crust of the earth, from which all the rocks and minerals which we know have been generated, must have contained, diffused through it, from the earliest time, all the elements which we now meet with in our study of the earth, whether still diffused, or accumulated, as we often find the rarer elements, in particular veins or beds.

The question now before us is, how have these elements thus been brought together, and why is it that they are not all still widely and universally diffused? Why are the compounds of iron in beds by themselves, copper, silver and gold gathered together in veins, and iodine concentrated in a few ores and certain mineral waters? That we may the better discern the direction in which we are to look for the solution of this problem, let us premise that all of these elements, in some of their combinations, are more or less soluble in water. There are, in fact, no such things in nature as absolutely insoluble bodies, but all, under certain conditions, are capable of being taken up by water, and again deposited from it. The alchemists sought in vain for a universal solvent, but we now know that water, aided in some cases by heat, pressure, and the presence of certain widely distributed substances, such as carbonic acid and alkaline carbonates and sulphides, will dissolve the most insoluble bodies; so that it may after all be looked upon as the long-sought-for alkahest or universal menstrum.

Let us now compare the waters of rivers, seas, and subterranean springs, thus impregnated with various chemical elements, with the blood which circulates through our own bodies. The analysis of the blood shows it to contain albuminoids which go to form muscle, fat for the adipose tissues, phosphate of lime for the bones, fluorides for the enamel of the teeth, sulphur, which enters largely into the composition of the hair and nails, soda, which accumulates in the bile, and potash, which abounds in the flesh-fluid. All of these are dissolved in the blood, and the great problem for the chemical physiologist is to determine how the living organism gathers them from this complex fluid, depositing them here and there, and giving to each part its proper material. This selection is generally ascribed to a certain vital force, peculiar to the living body. I shall not here discuss the vexed question of the nature of the force which determines the assimilation from the blood of these various matters for the needs of the animal organism, further than to say that modern investigations tend to show that it is only a subtler kind of chemistry, and that the study of the nature and relation of colloids and crystalloids, and of the phenomena of chemical diffusion, promises to subordinate all these obscure physiological processes to chemical and physical laws.

Let us now see how far the comparison which we have made between the earth and an animal organism will help us to understand the problem of the distribution of minerals in nature; how far water, the universal solvent, acting in accordance with known chemical and physical laws, will cause the separation of the mixed elements of the earth's crust, and their accumulation in veins and beds in the rocks. The subject is one of great importance to the geologist, who has to consider the genesis of the various rocks and ore-deposits, and the relations, which we are only beginning to un-

derstand, between certain metels and particular rocks, and between certain classes of ores and peculiar mineralogical and geological conditions. It is at the same time a vast one, and I can to-night only give you a few illustrations of the chemistry of the earth's crust, and of the laws of the terrestrial circulation, which I have compared to that of the blood distributing throughout the animal frame the elements necessary for its growth. The analogy is not altogether new, since a great French geologist, Elie de Beaumont, has already spoken of a terrestrial circulation in regard to certain elements in the earth's crust; though he has not, so far as I am aware, carried it out to the extent which I propose to-night in my attempt to explain some of the laws which have presided over the distribution of metals in the earth.

The chemist in his laboratory takes advantage of changes of temperature, and of the action of various solvents and precipitants, to separate, in the humid way, one element from another; but to these agencies, in the economy of nature, are added others which we have not yet succeeded in imitating, and which are exerted only in growing animals and plants. I repeat it, I do not wish to say that these latter processes are different in kind from those which we command in our laboratories, but rather that these organisms control a far finer and more delicate chemical and physical apparatus than we have yet invented. Plants have the power of selecting from the media in which they live the elements necessary for their support. The growing oak and the grass alike assimilate from the air and water the carbon, hydrogen, nitrogen, and oxygen which build up their tissues, and at the same time take from the soil a portion of phosphorous, which, though minute, is in both cases essential to the vegetable growth. The acorn of the oak and grass alike become the food of animals, and the gathered phosphates pass into their bones, which are nearly pure phosphate of lime. In like manner the phosphates from organic waste and decay find their way to the sea, and through the agency of marine vegetation become at last the bony skeletons of fishes. These are, in turn, the prey of carnivorous birds, whose exuviæ form on tropical islands beds of phosphatic guano. A history not dissim lar will explain the origin of beds of coprolites and other deposits of mineral phosphates.

But again, these plants or these animals may perish in the sea and be buried in its ooze. The phosphates which they have gathered are not lost, but become fixed in an insoluble form in the clayey matter; and when in the revolutions of ages, these sea-muds, hardened to rock, become dry land, and crumble again to soil, the phosphates are there found ready for the wants of vegetation.

Most of what I have said of phosphates applies equally to the salts of potash, which are not less necessary to the growing plant. From the operation of these laws it results that neither of these elements is found in large quantities in the ocean. This great receptacle of the drainage from the land contains still smaller quantities of iodine; in fact, the traces of this element present in sea-water can scarcely be detected by our most delicate tests. Yet marine plants have the power of separating this iodine, and accumulating it in their tissues, so that the ashes of these plants are not only rich in phosphates and in potash-salts, but contain so much iodine that our supplies of this precious element are almost wholly derived from this source, and that the gathering and burning of sea-weed for the extraction of iodine is in some regions an important industry. When this marine vegetation decays, the iodine which it contains, appears, like the potash and phosphates, to pass into combinations with metals, earths, or earthy phosphates, which retain it in an insoluble state, and in certain cases yield it to percolating saline solutions, which thus give rise to springs rich in iodine.

In all of these processes, the action of organic life is direct and assimilative, but there are others in which its agency, although indirect, is not less important. I can hardly conceive of an accumulation of iron, copper, lead, silver, or gold, in the production of which animal or vegetable life has not either directly or indirectly been necessary, and I shall begin to explain my meaning by the case of iron. This, you are aware, is one of the most widely diffused elements in nature; all soils, all plants contains it; and it is a necessary element in our blood. Clays and loams contain, however, at best, two or three hundredths of the metal, but so mixed with other matters that we could never make it available for the wants of

this iron age of ours. How does it happen that we also find it gathered together in great beds of ore, which furnish an abundant supply of the metal? The chemist knows that the iron, as diffused in the rocks, exists chiefly in combination with oxygen, with which it forms two principal compounds; the first, or protoxide, which is readily soluble in water impregnated with carbonic acid or other feeble acids, and the second, or peroxide, which is insoluble in the same liquids. I do not here speak of the magnetic oxide, which may be looked upon as a compound of the other two, neutral and indifferent to the most natural chemical agencies. The combinations of the first oxide are either colorless or bluish or greenish in tint, while the peroxide is reddish-brown, and is the substance known as iron-rust. Ordinary brick-clays are bluish in color, and contain combined iron in the state of protoxide, but when burned in a kiln they become reddish, because this oxide absorbs from the air a further proportion of oxygen, and is converted into peroxide. But there are clays which are white when burned, and are much prized for this reason. Many of these were once ferruginous clays, which have lost their iron by a process everywhere going on around us. If we dig a ditch in a moist soil which is covered with turf or with decaying vegetation, we may observe that the stagnant water which collects at the bottom soon becomes coated with a shining, iridescent scum, which looks somewhat like oil, but is really a compound of peroxide of iron. The water as it oozes from the soil is colorless, but has an inky taste from dissolved protoxide of iron. When exposed to the air, however, this absorbs oxygen, and peroxide is formed, which is no longer soluble, but separates as a film on the surface of the water, and finally sinks to the bottom as a reddish ochre, or, under somewhat different conditions, becomes aggregated as a massive iron ore. A process identical in kind with this has been at work at the earth's surface ever since there were decaying organic matters, dissolving the iron from the porous rocks, clays, and sands, and gathering it together in beds of iron ore or iron ochre. It is not necessary that these rocks and soils should contain the iron in the state of protoxide, since these organic products (which are themselves dissolved in the water) are able to remove a portion of the oxygen from the insoluble peroxide, and convert it into the soluble protoxide of iron, being themselves in part oxidized and converted into carbonic acid in the process.

We find in rock formations of very different ages beds of sediments which have been deprived of iron by organic agencies, and near them will generally be found the accumulated iron. Go into any coal region, and you will see evidences that this process was at work when the coal-beds were forming. The soil in which the coal-plants grew has been deprived of its iron, and when burned turns white, as do most of the slaty beds from the coal-rocks. It is this ancient soil which constitutes the so-called fire-clays, prized for making fire-bricks, which, from the absence of both iron and alkalies, are very infusible. Interstratified with these we often find, in the form of ironstone, the separated metal; and thus from the same series of rocks may be obtained the fuel, the ore, and the fire-clay.

From what I have said it will be understood that great deposits of iron ore generally occur in the shape of beds; although waters holding the compounds of iron in solution have, in some cases, deposited them in fissures or openings in the rocks, thus forming true veins of ore, of which we shall speak further on. I wish now to insist upon the property which dead and decaying organic matters possess of reducing to protoxide, and rendering soluble, the insoluble peroxide of iron diffused through the rocks; and reciprocally the power which this peroxide has of oxidizing and consuming these same organic matters, which are thereby finally converted into carbonic acid and water. This last action, let me say in passing, is illustrated by the destructive action of rusting iron fastenings on moist wood, and the effect of iron-stains in impairing the strength of linen fibre.

We see in the coal formation that the vegetable matter necessary for the production of the iron-ore beds was not wanting; but the question has been asked me, where are the evidences of the organic material which was required to produce the vast beds of iron ore found in the ancient crystalline rocks? I answer, that the organic matter was, in most cases, entirely consumed in producing these great

results; and that it was the large proportion of iron diffused in the soils and waters of those early times, which not only rendered possible the accumulation of such great beds of ore, but oxidized and destroyed the organic matters which in later ages appear in coals, lignites, pyroschists, and bitumens. Some of the carbon of these early times is, however, still preserved in the form of graphite, and it would be possible to calculate how much carbonaceous material was consumed in the formation of the great iron-ore beds of the older rocks, and to determine of how much coal or lignite they are the equivalents.

In the course of ages, however, as a large proportion of the once diffused iron-oxide has become segregated in the form of beds of ore, and thus removed from the terrestrial circulation, the conditions have grown more favorable for the preservation of the carbonaceous products of vegetable life. The crystalline magnetic and specular oxides, which constitute a large proportion of the ores of this metal, are almost or altogether indifferent to the action of organic matter. When, however, these ores are reduced in our furnaces, and the resulting metal is exposed to the oxidizing action of a moist atmosphere, it is again converted into iron-rust, which is soluble in water holding organic matters, and may thus be made to enter once more into the terrestrial circulation.

There is another form in which iron is frequently concentrated in nature, that of sulphide, and most frequently as the bisulphide known as iron-pyrites. This substance is found both in the oldest and the newest rocks, and, like the oxide of iron, is even to-day forming in certain waters, and in beds of mud and silt, where it sometimes takes a beautifully crystalline shape. What are the conditions in which the sulphide of iron is formed and deposited, instead of the oxide or carbonate of iron? Its production depends, like these, on decaying organic matters. The sulphates of lime and magnesia, which abound in sea-water, and in many other natural waters, when exposed to the action of decaying plants or animals, out of contact of air, are, like peroxide of iron, deoxidized, and are thereby converted into soluble sulphides; from which, if carbonic acid be present, sulphuretted hydrogen gas is set free. Such soluble sulphides, or sulphuretted hydrogen, are the reagents constantly employed in our laboratories to convert the soluble compounds of many of the common metals, such as iron, zinc, lead, copper, and silver, into sulphides, which are insoluble in water and in many acids, and are thus conveniently separated from a great many other bodies. Now, when in a water holding iron-oxide, sulphates are also present, the action of organic matter, deoxidizing the latter, furnishes the reagent necessary to convert the iron into a sulphide; which in some conditions, not well understood, contains two equivalents of sulphur for one of iron, and constitutes iron-pyrites. I may here say that I have found that the unstable protosulphide, which would naturally be first formed, may, under the influence of a persalt of iron, lose one-half of its combined iron; and that from this reaction a stable bisulphide results. This subject of the origin of iron-pyrites is still under investigation.

The reducing action of organic matters upon soluble sulphates is well seen in the sulphuretted hydrogen which is evolved from the stagnent sea-water in the hold of a ship, and which coats silver exposed to it with a black film of sulphide of silver, and for the same reason discolors white-lead paint. The presence of sulphur in the exhalations from some other decaying matters is well known, and in all these cases a soluble compound of iron will act as a disinfectant, partly by fixing the sulphur as an insoluble sulphide. Silver coins brought from the ancient wreck of a treasure-ship in the Spanish Main were found to be deeply incrusted with sulphide of silver, formed in the ocean's depths by the process just explained, which is one that must go on wherever organic matters and sea-water are present, and atmospheric oxygen excluded.

The chemical history of iron is peculiar; since it requires reducing matters to bring it into solution, and since it may be precipitated alike by oxidation, and by farther reduction, provided sulphates are present. The metals copper, lead, and silver, on the contrary, form compounds more or less soluble in water, from which they are not precipitated by oxygen, but only by reducing agents, which may separate them in some cases in a metallic state,

but more frequently as sulphides. The solubility of the salts and oxides of these metals in water is such that they are found in many mineral springs, in the waters that flow from certain mines, and in the ocean itself, the waters of which have been found to contain copper, silver, and lead. Why, then, do not these metals accumulate in the sea, as the salts of soda have done during long ages? The direct agency of organic life comes again into play, precisely as in the case of phosphorus, iodine, and potash. Marine plants, which absorb these from the sea-water, take up at the same time the metals just named, traces of all of which are found in the ashes of sea-weeds. Copper, moreover, is met with in notable quantities in the blood of many marine molluscous animals, to which it may be as necessary as iron is to our own bodies. Indeed, the blood of man, and of the higher animals, appears never to be without traces of copper as well as of iron.

In the open ocean the waters are constantly aerated, so that soluble sulphides are never formed, and the only way in which these dissolved metals can be removed and converted into sulphides is by fixing them in organisms, either vegetable or animal. These, by their decay in the mud of the bottom, or the lagoons of the shore, generate the sulphides which fix their contained metals in an insoluble form, and thus remove them from the terrestrial circulation.

It is not, however, in all cases necessary to invoke the direct action of organisms to separate from water the dissolved metals. It often happens that the waters containing these, instead of finding their way to the ocean, flow into lakes or inclosed basins, as in the case of the drainage-waters of an English copper-mine, which have impregnated the turf of a neighboring bog to such an extent that its ashes have been found a profitable source of copper. Under certain conditions, not yet well understood, this metal is precipitated by organic matters in the metallic state, but if sulphates are present a sulphide is formed. Thus, in certain mesozoic schists in Bohemia, sulphide of copper is found incrusting the remains of fishes, and in the sandstones of New Jersey we find it penetrating the stems of ancient trees. I have in my possession a portion of a small trunk taken from the mud of a spring in Ontario, in which the yet undecayed wood of the centre is seen to be incrusted by hard metallic iron-pyrites. In like manner the old trees of the New Jersey sandstone became incrusted with copper-sulphide, which, as decay went on, in great part replaced the woody tissue. Similar deposits of copper and of iron often took place in basins where the organic matter was present in such a condition or in such quantity as to be entirely decomposed, and to leave no trace of its form, unlike the examples just mentioned. In this way have been formed fahl-bands, and beds of pyrites and other ores.

The fact that such deposits are associated with silver and with gold leads to the conclusion that these metals have obeyed the same laws as iron and copper. It is known that both persalts of iron and soluble sulphides have the power of rendering gold soluble, and its subsequent deposition in the metallic state is then easily understood.

I have endeavored by a few illustrations to show you by what processes some of the more common metals are dissolved and again separated from their solution in insoluble forms. It now remains to say somewhat of the geological relations of ore deposits, which are naturally divided into two clauses; the first including those which occur in beds, and have been formed contemporaneously with the inclosing earthy sediments. Such are the beds of iron-ores which often hold imbedded shells and other organic remains, and the copper-bearing strata already mentioned, in which the metal must have been deposited during the decay of the animal or plant which it incrusts or replaces. But there are other ore deposits evidently of more recent formation than the rocky strata which inclose them, which have resulted from a process of infiltration, filling up fissures with the ore, or diffusing it irregularly through the rock. It is not always easy to distinguish between the two classes of deposits. Thus a fissure may in some cases be formed and filled between two sundered beds, from which may result a vein that may be mistaken for an interposed stratum. Again, a bed may be so porous that infiltrating waters may diffuse through it a metallic ore, or a metal, in such a manner as to leave it doubtful whether the process was contemporaneous with the disposition of the bed, or posterior to it. But I wish to

speak of deposits which are evidently posterior, and occupy fissures in previously formed strata, constituting true veins. Whether produced by the great movements of the earth's crust, or by the local contraction of the rocks (and both of these causes have in different cases been in operation), such fissures sometimes extend to great lengths and depths; their arrangement and dimensions depending very much on the texture of the rocks which have been subjected to fracture. When a bone in our bodies is broken, nature goes to work to repair the fractured part, and gradually brings to it bony matter, which fills up the little interval, and at length makes the severed parts one again. So when there are fractures in the earth's crust, the circulating waters deposit in the openings mineral matters, which unite the broken portions, and thus make whole again the shattered rocks. Vein-stones are thus formed, and are the work of nature's conservative surgery.

Water, as we have seen, is a universal solvent, and the matters which it may bring and deposit in the fissures of the earth are very various. There is scarcely a spar or an ore to be met with in the stratified rocks that is not also found in some of these vein-stones, which are often very heterogeneous in composition. In certain veins we find the elements of limestone or of granite, and these often include the gems, such as amethyst, topaz, garnet, hyacinth, emerald, and sapphire; while others abound in native metals or in metallic oxides or sulphides. The nature of the materials thus deposited depends very much on conditions of temperature and of pressure, which affect the solvent power of the liquid, and still more upon the nature of the adjacent rocks and of the waters permeating them. The chemistry of mineral veins is very complicated. Many of these fissures penetrate to a depth of thousands of feet of the earth's crust, and along the channels thus opened the ascending heated subterranean waters may receive in their course various contributions from the overlying strata. From these additions, and from the diminished solubility resulting from a decrease of pressure, deposits of different minerals are formed upon the walls, and the slow changes in composition are often represented by successive layers of unlike substances. The power of these waters to dissolve and bring from the lower strata their contained metals and spars is probably due in great part to the alkaline carbonates and sulphides which these waters often hold in solution; but the chemical history of the deposition of the ores of iron, lead, copper, silver, tin, and gold, which are found in these veins, demands a lengthened study, and would furnish not less beautiful examples of nature's chemistry than those I have already laid before you.

The process of filling veins has been going on from the earliest ages; we know of some which were formed before the Cambrian rocks were deposited, while others are still forming, as the observations of Phillips have shown us in Nevada, where hot springs rise to the surface and deposit silica, with metallic ores, which incrusts the walls of the fissures. These thermal waters show that the agencies which in past times gave rise to the rich mineral deposits of our Western regions, are still at work there.

Let us now consider the beneficent results of the process of vein-making. The precious metals, such as silver, are so sparsely distributed, that even the beds rich in the products of decaying sea-weed, which we have supposed to be deposited from the ocean, would contain too little silver to be profitably extracted. But in the course of ages these sediments, deeply buried, are lixiviated by permeating solutions, which dissolve the silver diffused through a vast mass of rock, and subsequently deposit it in some fissure, it may be in strata far above, as a rich silver ore. This is nature's process of concentration.

We learn from the history which we have just sketched the important conclusion, that amid all the changes of the face of the globe the economy of nature has remained the same. We are apt, in explaining the appearances of the earth's crust, to refer the formation of ore-beds and veins to some distant and remote period, when conditions very unlike the present prevailed, when great convulsions took place, and mysterious forces were at work. Yet the same chemical and physical laws are now, as then, in operation; in one part dissolving the iron from the sediments and forming the ore-beds, in another separating the rarer metals from the ocean's waters; while in still other regions the consolidated and buried sediments are per-

meated by heated waters, to which they give up their metallic matters, to be subsequently deposited in veins. These forces are always in operation, rearranging the chaotic admixture of elements which results from the constant change and decay around us. The laws which the first great cause imposed upon this material universe on the first day are still irresistibly at work fashioning its present order. One great design and purpose is seen to bind in necessary harmony the operations of the mineral with those of the vegetable and animal worlds, and to make all of these contribute to that terrestrial circulation which maintains the life of our mother earth.

While the phenomena of the material world have been looked upon as chemical and physical, it has been customary to speak of those of the organic world as vital. The tendency of modern investigation is, however, to regard the processes of animal and vegetable growth as themselves purely chemical and physical. That this is to a great extent true must be admitted, though I am not prepared to concede that we have in chemical and physical processes the whole secret of organic life. Still we are, in many respects, approximating the phenomena of the organic world to those of the mineral kingdom; and we at the same time learn that these so far interact and depend upon each other that we begin to see a certain truth underlying the notion of those old philosophers who extended to the mineral world the notion of a vital force; which led them to speak of the earth as a great living organism, and to look upon the various changes in its air, its waters, and its rocky depths, as processes belonging to the life of our planet.

[Since this lecture was delivered, I have seen the results of the researches of Sonstadt on the iodine in sea-water, which appear in the "Chemical News" for April 26, May 17, and May 24, 1871. According to him this element exists in sea-water, under ordinary conditions, as iodate of calcium, to the amount of about one part of the iodate in 250,000 parts of the water. This compound, by decaying organic matter (and by most other reducing agents,) is changed to iodide, from which, apparently by the action of carbonic acid, iodine is set free, and may be separated by agitating the water with bisulphide of carbon. The iodine thus liberated from sea-water by the action of dead organic matters, however, slowly decomposes water in presence of carbonate of calcium, and is reconverted into iodate, the oxygen of the air probably intervening to complete the oxidation, since, according to Sonstadt, iodides are readily converted into iodates under these conditions. He finds that the insolubility of the iodides of silver and of copper is so great that by the use of salts of these metals iodine may be separated from sea-water without concentration, provided the iodate of calcium has first been reduced to iodide. By this property of iodine and its compounds to oxidize and be oxidized in turn, Sonstadt supposes them to perform the important function of consuming the products of organic decay, and so maintaining the salubrity of the ocean's waters. Their action would thus be very similar to that of the oxides of iron, as explained in the present lecture.

Still more recently the same chemist has announced that the sea-water of the British coasts contains in solution besides silver an appreciable quantity of gold, estimated by him at about one grain to a ton of water. This is separated by the addition of chloride of barium, apparently as an aurate of baryta adhering to the precipitated sulphate, which yields by assay an alloy of about six parts of gold to four of copper. Other methods have been devised by him for separating these metals from their solution in sea-water. The agent which keeps the gold of the sea in a soluble and oxidized condition is, according to Sonstadt, the iodine liberated by the action already described.

The views maintained by Lieber, Wurtz, Genth, and Selwyn, as to the solution and redeposition of gold in modern alluvial deposits seem to be well grounded, and we are led to the conclusion that the circulation of this metal in nature is as easily effected as that of iron or of copper. The transfer of certain other elements, such as titanium, chrome, and tin, or at least their accumulation in concentrated forms, appears, on the contrary, to require conditions which are no longer operative at the surface of the earth.

It should here be noticed that Prof. Henry Wurtz, of New York, in a paper read before the American Association for the Advancement of Science, in 1868, expressed the opinion that the ocean-waters

contained gold, and urged experiments for its detection. According to his calculations the total amount of gold hitherto extracted from the earth, and estimated at two thousand million dollars, would give only one dollar for two hundred and eighty million tons of sea-water, while from the experiments of Sonstadt, it would appear that the same quantity of gold is actually contained in twenty-five tons of water.]

## ON THE IMPORTANCE OF SURVEYING IN GEOLOGY.

By BENJAMIN SMITH LYMAN, C. E.

Transactions of American Institute of Mining Engineers.

The importance of topography to geology is so commonly underrated as to deserve to be pointed out again and again. The relation of topography to the different branches of geology may be seen best by a glance at them all.

Geology is well understood to consist of the observation of facts about rocks as materials of the earth (geognosy), and the explanation of those facts (geogeny).

The facts to observe are:

I. GEOMETRICAL, as (1) *structure*, including the dip and strike at different points, the size, shape, and position of basins and saddles; (2) *vertical section*, that is, the thickness of rock groups and of their parts; (3) *horizontal* or geographical *position*.

II. PHYSICAL, such as *texture;* whether sedimentary or crystalline; and, if crystalline, whether granitic, porphyritic, amygdaloidal, globular or concretionary; whether *compact or granular; coarse or fine; pervious or impervious: hard or soft; firm or tender; with cleavage or without; massive or thin; the microscopic structure; also, whether magnetic or not; soluble or insoluble; fusible or infusible;* and the *constituent minerals.*

III. CHEMICAL, that is, the composition of the rocks and of their minerals and their affinities.

IV. PALÆONTOLOGICAL, as what kind of fossils are in the rocks, whether (1) *salt-water;* and if so, whether (*a*) deep-water; (*b*) shallow-water; or (*c*) lagoon; (2) *fresh-water;* or (3) *land.*

Knowledge of this general character about the fossils is all that is needed of them for geological purposes, for understanding the nature of the rocks and the successive changes the earth has undergone. The special fossils that may be found in different beds of rock may be of great interest in the history of life in the world, or of organisms (palæontology), and may sometimes give more or less trustworthy aid in determining practically the relative age of such beds, but in general it is rather the position of the beds that determine the relative age of the different groups of animals or plants whose remains are found in them; and geology gives to palæontology far more in value than it gets in return. It is absurd, then, for palæontology to assume to be geology, or the chief part of geology, as so often happens nowadays. Palæontology in truth only helps to a knowledge of a very few of the many physical and chemical facts about the earth's materials, and those few perhaps seldom of very great importance. The explanation of the changes from bed to bed in the general character of the fossils, as salt water, fresh-water, or land, deep-water or shallow-water fossils, depends, of course, on physical or chemical laws.

The facts that were just now called geometrical are, of course, in one sense, merely physical; for they only concern the size, shape, position, and general composition of rocks or groups of rocks. The explanation of such facts must always be of a physical or chemical nature.

It is plain, then, that both the facts of geology and their explanation are always either physical or chemical, with the not very important exception that the general character of fossils is shown by physiology.

The facts learned by measurement, though they can scarcely be separated wholly from the other classes of facts, do not yield to them in importance. The questions, where a rock of a given physical or chemical nature is found, what is its extent, and what is its position relative to other rocks, and to the sea level, are at least as important as the physical and chemical facts themselves, both in theoretical geology and in practical mining. Indeed, the geometrical facts of themselves would some-

times show some of the most important physical facts; as, for example, the shape of the surface of the ground very often shows the relative hardness of the rocks that underlie it, and in a limited region shows by that means what beds of a known series underlie given points, such as a coal-bed marked at its outcrop by a terrace, or a hard bed of rock marked by a ridge. For a thorough understanding of geology, of course, an intimate acquaintance with the laws of physics and chemistry would be needed; but for most practical and even theoretical purposes only that common knowledge of them is wanted which almost every man has, and geometrical measurements become the sole and all-important requirement.

The necessity of some sort of geometrical representation of some of the most important geological facts has been acknowledged almost universally by the use of maps, and of more or less rudely made sections. But it is perhaps the very imperfection of such methods as have been commonly employed, that has brought this branch of geological work into the undeserved contempt in which it seems generally to lie; and such geometrical representation has at best almost always been used solely to set forth geological facts, seldom as a means of finding them out. Very often, indeed, the map is merely to show the geographical distribution of different groups of fossil animals and plants. Even when hills and mountains are shown, it is only by vague shading or indefinite hachure lines with all traces of geological structure left out. The cross-section, with its exaggerated vertical scale and distorted dips, would commonly seem rather to impress the eye with the varying height of surface than to show how the rocks lie, the true aim of a geological section. The map and section not only give the geological facts so very imperfectly, but are almost useless as an aid in working out the geology, from the bare, disconnected facts observed in the field, and in correcting or verifying the guesses made there.

A geological map should be a geometrical construction on paper of the earth's features on the surface and below, and should show as fully as possible the shape of the surface, marked with the places of the observed rocks, and should give the position of the rocks or of some of the chief beds of rock below the surface as well as on it; and should be accompanied by a section, to show the thickness and sequence of the rock-beds, as well as by a cross-section of the region, to show the dips and basins of the rocks.

The relative position of points on the ground is found, of course, by the measurement of horizontal distances and angles; the height of points is found by levelling, that is, the measurement of vertical distances. The points of reference on the surface are well enough mapped by any of the ordinary methods, but the shape of the surface is far better shown by contour lines (or lines of equal height) than by hachures (lines of great steepness) or shading (dark according to the steepness). Where the map is on a large scale, the contour lines may be ten feet apart in level, or even less, and show many details. But even in maps of large regions on a small scale, contour lines, although 100, or as much as 250 feet apart in level, or even more, so that many details must be left out, still give very much more information than hachures or shading, and show, roughly at least, the height of mountains, besides their course and steepness; and on comparatively level ground, where hachures and shading have nothing whatever to say, contour lines show not only the height, but the direction of the slopes and their steepness.

Shading aims only to show the steepness of the ground, and at the very best can do this only very roughly indeed. Hachures aim to show the steepness and its direction; but can show the steepness no better than shading, and to show well even the direction of greatest steepness, would often need far greater delicacy of touch and of eye than either is capable of. Neither shading nor hachures give even a rough idea of the relative height of the ground at different points. Contour lines, on the other hand, show with more or less exactness the height of every point on the surface, besides giving with great nicety both the direction of greatest steepness and its amount. There is, indeed, no comparison between the merits of contour lines and those of either of the other two methods; and the only plausible explanation of the fact that contour lines are comparatively so seldom used is, that they are definite in their statements, they exact for their preparation a more definite knowledge of the shape of the ground, or at least a clearer idea of it, and consequently greater labor. Shading and hachures furnish a vague language that is fitted for expressing with ease vague infor-

mation; what contour lines tell, they tell with precision. If the information at hand be imperfect, contour lines will still express with clearness the best opinion or guess that can be given by the mapmaker, whose guess even may be of great value to those who have not had his means of forming an opinion. The uncertainty of the information should at the same time be shown by the wording of the title of the map, or by a note upon it, or by dotting the contour lines. Indeed, any desired degree of vagueness can be given by leaving the distance apart of the contour lines indefinite, or only more or less approximately uniform. The advantage of contour lines over hachuring has been well insisted on in Lesley's "Manual of Coal and its Topography," 1856, but cannot be urged too often, until it is generally acknowledged and they come into common use.

It is very easy to give the appearance of relief to the map by thickening the contour lines, on one side of the hills, and by altogether leaving out half of them on the other side, so that the hills may look as if they were lighted by the sun on one side, and in the shade on the other. But some confusion might arise in reading the map, because this very effect of dark shade is also given by the mere closeness of the contour lines which marks steepness of the ground. A dark shaded part may seem steeper than it really is, and a really steep place on the sunny side of a hill may, from the omission of half the contour lines, seem only half as steep as it is. It is, perhaps, better to give the relief effect by mere shading; heavy shading on one side of the hills, and light shading, or none at all, on the other side, leaving the contour lines of uniform thickness, to show the steepness of the ground by their closeness. Confusion would especially be guarded against by making the contour lines of a different color from the shading.

As contour lines give the best means of showing on paper the shape of the surface of the ground, so they give likewise the best means of showing on paper the shape of the surface of a bed of rock. It is seldom that the surface of a bed of rock is laid bare for any great distance by nature, so that it can be mapped like the surface of the ground; but it often happens that this can be done in mines. In other cases it is necessary to map the bed and draw its contour lines with more or less certainty from the exposures that happen to be visible. Not only may the actual exposures of the bed itself be regarded, but as the beds above and below are more or less exactly parallel, its position can be reckoned from an observation of theirs. At each point of observation the strike and dip of the rocks must be taken as well as their level, just as in making observations for mapping the surface of the ground; besides taking the level of a point, the contour lines near it are at least sketched; that is, the direction of a level line, and the steepness at right angles with it, are more or less exactly taken. If such observations on the rocks are made at points enough, a perfect geometrical representation of any bed of rock can be made. Even if the observations are too few for that, they may yet be enough to form a reasonable conjecture as to the position of the bed, with more or less certainty. The very putting down on paper with precision, in proper relation, what is known of the position of the rocks, aids immensely in completing a geometrical construction of them, and gives a vast deal of information beyond what can be guessed at in the field. The eye takes in readily such mapped observations, and sees their bearing upon each other, when the biggest head, with the same facts, but without a map, would be at fault, and merely muddled.

The known or conjectured shape of the surface of the bed can be shown on paper better by contour lines than in any other way, and is generally so much more regular than the shape of the surface of the ground that the contour lines of one will not be mistaken for those of the other, even if they be drawn in the same color on the same sheet; and sometimes even several different beds may be drawn without confusion. The points where the contour lines of the bed meet the same contour lines of the surface, show the position of the outcrop of the bed, one of the most important features to map, whether for practical or for theoretical purposes. It is, in fact, the geometrical construction itself, that commonly shows the position of the outcrop through most of its length, very often where it would not otherwise be suspected.

If the dips are very steep it will often not be well to make the contour lines of a rock-bed (the underground contour lines) as near together in level as those of the surface; they may be a hundred feet apart in level instead of ten, and yet show perfectly well

the shape of the bed. Sometimes it is shown very well merely by the outcrop and a single contour line, that, for example, of the drainage level of the region, or the course that a drift for drainage would take on the bed in question. With surface contour lines and underground contour lines, the depth of the bed below the surface at any point can readily be known; and this is highly important in sinking a shaft or reckoning the yield of a bed above a given level.

With such a complete geometrical representation of the shape of a bed as contour lines would give, it is only needful to make a full section of all the beds with their thickness to show the position of every bed of rock at every point. The thickness of each bed in its order must be measured, of course, at right angles with its surface; and a drawing of the whole series made to show them all on the same scale. It is plain that the whole series need not be measured at one point, but the different parts can be taken wherever exposed. The geometrical construction of the map will help very much to show their relation, and the gaps between them, if any.

Having the surface of the ground and that of one or more rock-beds shown by contour lines, and a section of all the rock-beds with their thickness, it is easy to draw a cross-section of the country in any direction, so as to show the profile outline of the ground and of each bed. Such a section across the average strike of the rocks or across the axes of their basins and saddles is especially useful; the next most useful section is commonly one along the axis of a basin. Of course the vertical and horizontal scale of such a section must be the same, otherwise the rock structure, the chief object of the section, would be greatly distorted. In making an undistorted cross-section before the underground contours are drawn, facts often come to light that would otherwise be unknown, such as the identification of beds exposed only at distant points, and the steepness of the dip at points where there is no exposure. Sections of this kind are, therefore, often a very great help in making the map itself.

Such maps and sections, then, show completely all that is known (or conjectured) of the geometrical facts of the beds of rock, the thickness, extent, position, and present shape of each bed, its position with reference to each of the other beds; the shape, size, and position of the basins and saddles, what part of each bed still remains underground, and what part has been worn away to form valleys, what part is above the lowest drainage level of the region or any other given level, and what below it; and the very process of making the maps and sections is a very valuable aid to gaining such knowledge, and often teaches as much as could be learned by very costly digging or mining. These facts are not only of the highest importance themselves, but they lie at the base of very much (if not most) reasoning toward the explanation of the purely physical and chemical facts of rock-beds.

Simple and clear as all this seems, yet it was so long overlooked and is still so much disregarded, that maps showing with the least completeness the geometrical facts of the surface and of the rock-beds were never seen thirty-five years ago, and are extremely rare even now. Pennsylvania, in fact, can claim for itself or for its citizens the credit of doing nearly all that has been done for the progress of this branch of geology, whose early history (in America at least) is but part of that of the Pennsylvania State Geological Survey, and whose later history is found in the geological work of the chief topographer of the survey, Professor J. P. Lesley, followed by that of others who have learned more or less directly from him. To him alone, in fact, belongs the credit of almost all the advances that have been made in this line of work, as well as of having first established its most essential principles. Some of its earlier hitherto unpublished annals, learned by inquiry of him, deserve to be recorded before it is too late.

The Pennsylvania Survey, under Professor H. D. Rogers, began in the year 1836, and soon discovered a very intimate relation between the surface features and the structure of the rock-beds below, a relation that is perhaps more striking in this State and Virginia than in most countries.

Early in the spring of 1839, one of the assistants of the survey, James D. Wheipley, finished in lead-pencil at the end of two years' work, all his own, the first topographical map. It embraced all the anthracite region except the Wyoming Valley.

In 1840 Alexander McKinley finished a sketch map of the Wyoming Basin.

Between the spring of 1839 and the fall of 1840, Andrew A. Henderson (now Surgeon in the United States Navy) made a beautiful map of the Juniata region, partly

copied into Lesley's "Manual of Coal and its Topography" (page 137). At the same time the country north of that was also mapped by McKinley.

In 1839 J. P. Lesley, who had just joined the survey, made in Whelpley's style a map of the country south of the anthracite region and north of the North (or Kittatinny) Mountains.

In 1840 and 1841, Lesley was occupied in completing Whelpley and McKinley's maps by putting in the surrounding country.

At the end of 1841 all the materials of the whole State where any mapping had been done went into Lesley's hands, and in 1841 and 1842 he made up the State map and its cross-sections.

In all these maps no contour lines were used, but great attention was paid to elevation for the cross-sections, and the maps were made with the sections before the eye as a guide in making the hachures, and Dr. Henderson was especially successful in this.

In the winter of 1846 and 1847, Lesley made a second copy of the State map and of all the sections across the State.

In 1851 he made a great map of the Shamokin anthracite region for Mr. Rogers, a private undertaking. The country was cross-barred with section-lines staked at short intervals; and the map was made with hachures on a peculiar system of Lesley's invention, equivalent to contour lines.

In 1852 Lesley spent the summer in the field in making (for the State survey again) a great sheet of the Pottsville anthracite region. The country above ground was cross-barred with lines three-quarters of a mile apart, and the outcrops were run by parties under charge of John Sheafer; while underground surveys were also made by parties under P. W. Sheafer, and Lesley did the mapping. Contours were drawn only to determine the depth of the hachures, which were all short, showing the slopes, with eight or ten systems on a single mountain-side. The outcrops in the gaps were marked by a peculiar system of hachures that showed the dip. Every outcrop of every coal-bed and every rock outcrop were laid down. The map was between twenty and thirty feet long, and has gone out of sight, but no doubt still exists among the papers left by Rogersat his death, since the State law made all the materials of the survey his private property.

At the end of 1852 it was finished only from near Donaldson and Tremont to within six or seven miles of Tamaqua, and embraced the Mine Hill basin and the plateau of the Broad Mountain. It was intended to carry forward and finish the map the next year; but the corps was broken up; and in 1853 A. A. Dalson, with one assistant, was employed to extend the sheets. Without parties he could not do it in the same way, and Rogers had him make out of all the materials extant the reduced copy of the map of the anthracite region (with hachures), published in the State Report under Lesley's and Dalson's names; but Lesley never saw it until it had been printed. It should be called Dalson's map, as the preface to the report does call it.

This and the great map of the State with its cross-sections, are all that was ever published of all this work.

The first countouring for geological maps was done in 1853 and 1854, in a great map of Lesley's for the Pennsylvania Railroad Company, of the country from Johnstown to Greensburg, in Western Pennsylvania, covering parts of Westmoreland, Fayette, and Indiana Counties. It was eight feet long and four feet wide, and was covered with fine contour lines twenty feet apart in level, and with intermediate ten-foot lines for relief, and shading on the southeast side of the hills. I myself saw this map about 1856 or 1857, and can bear witness that it was a very wonder of topographical labor and skill. It would seem years ago to have disappeared from existence, but it is incredible that so valuable a piece of work should be destroyed.

In 1855 and 1856 Lesley mapped Broad Top Mountains with contour lines; and the survey was so minute that there were over eleven thousand stations levelled. None of this has ever been published, and it would be an extremely valuable contribution to another State survey.

In 1856 he published his "Manual of Coal and its Topography," in which he set forth most admirably the relations of topography to geology, and make public the principles of the art to which he himself had first given form. The book contains many beautiful little topographical maps and sketches by way of illustration. From that time to the present (owing partly to the increased ease of reproducing maps by the help of photography, and photolithography), he has published many specimens of his work,

especially in the Proceedings and Transactions of the American Philosophical Society, as well as in the pamphlets of private owners of mineral lands; and much remains unpublished. The maps cover many points in the Appalachian region from Cape Breton to Georgia, but particularly in Pennsylvania, and are sometimes in contour lines, with or without shading in addition, sometimes only in shading. The position of beds (say of coal or iron), is shown on them by laying down their outcrop and the course of a level upon the bed, for example the lowest water-level of the tract or region. The maps are sometimes colored and sometimes not. They show not only very great topographical and geological knowledge and experience, but high artistic taste and skill.

In 1866 and 1867, the feasibility of using underground contour lines, to give the shape of rock-beds (sometimes of three or four above one another), was proved on some Southwestern Virginia coal, iron, and lead maps of my own; a photograph of one of which was shown to the meeting of the American Association for the Advancement of Science, in 1867, at Burlington. A number of such maps have been made since that, but the only printed ones are in my "Report on the Punjab Oil Lands, Lahore," 1870. They were all drawn with special reference to the requirements of photography.

In the last three years, and especially within the last year, contour lines have come a little more generally into use for geological purposes, no doubt solely through Lesley's example and teaching. R. P. Rothwell, J. W. Harden, S. F. Emmons, A. Hague, T. B. Brooks, J. F. Blandy, and perhaps others, have published good works of this kind; not all of them, however, marking the position of the beds of rock even by an outcrop line, still less by a level.

## SEWAGE FARMS.

"The Engineer."

It is frequently assumed that a principle must be unsound because its application to practice cannot be rendered remunerative. People neglect to inquire into the nature and condition of the practice, but at once lay the blame on the principle, and attribute to the cause what in reality belongs to the effect. Such a course is in many instances the easiest mode of getting rid of a difficulty. Too rigid an inquiry into the details of the practical execution of a project might, and frequently would, demonstrate that the failure in a pecuniary sense was due, not to any defect inherent in the scheme itself, but to the blunders and incompetency of those engaged in carrying it out. Unluckily, the evil effect of practical failures of this character, more especially with regard to projects of a comparatively new and untried description, is not confined to individual instances, nor to the immediate locality where they occur. The whole affair gets a bad name. A stop is put to further trials and experiments which would have been undertaken but for the prediction of financial failure; a prediction which, with respect to the subject of our article, is based upon no other grounds than the want of success which, in a pecuniary sense, has attended some examples of the use of sewage, under conditions in which no other result could have been expected. While the progress of sewage irrigation has thus been retarded, one benefit has resulted. The illusory nature of the thousand and one patents and methods for deodorizing, purifying, and utilizing sewage by any means save that of irrigation, has been thoroughly demonstrated. Local boards and sanitary authorities are now completely convinced of the soundness of the principle of sewage irrigation. The question is: Can it be made to pay? This question we shall now consider. The principle of sewage irrigation, which in its full scope includes the establishment and maintenance of sewage farms, has long ago been acknowledged to be sound, even by its enemies. It accomplishes at one operation the double duty of fertilizing the soil and purifying the effluent water. In fact, the one result is consequent upon the other. The fertilization of the soil signifies nothing more nor less than the abstraction from the sewage of those very ingredients which render an effluent water in which they may happen to remain noxious and impure, and totally unfit to be

permitted to flow into any river or natural watercourse. If it be granted that the utilization of sewage is synonymous with its application in some form or another to the land, it is obvious that the simpler and the readier the method by which that application is effected the better. Of all methods, that of irrigation is unquestionably the simplest and easiest. It applies the sewage to the soil in the manner most congenial to it, and most favorable to the development of that wonderful power of assimilation with which plants of every description are endowed. If, as is universally acknowledged, irrigation *per se*, without any regard to the fertilizing qualities of the liquid, be of very great advantage to land, the benefit must be very materially enhanced when the liquid in addition is possessed of a high manurial value. In this case no previous preparation, no chemical fortifying, no adventitious strength is imparted to the manure. It acts solely by its own specific virtue, and requires but the land necessary for its application. This desideratum brings us at once to the pecuniary question, of which it constitutes the most important element. Sewage farms have proved remunerative, do prove remunerative, and under certain fair and reasonable conditions will prove remunerative. That all have not done so there is no doubt, but an inquiry into the cause will speedily demonstrate that no other result, taking the circumstances into consideration, could have ensued.

An example in point will probably best corroborate our views. Some years ago sewage irrigation was carried on, by a company, over a tolerably large area of land, some three or four hundred acres, not very far from London. The rent was moderate, the farm was well managed and well cared for, and at the end of three successively favorable seasons the company were enabled to pay a dividend of over ten per cent. Now for the sequel. No sooner did the head landlords or owners of the land—who in this instance constituted a corporate authority directly interested in the benefit which the sewage farm, as a great sanitary measure, conferred upon their town—hear of the manner in which the farm was paying than they took the first opportunity of putting an effectual stop to profits. They just doubled the rent. At this juncture also several successive very wet seasons intervened. A change by no means to the advantage of the company was made in the management, arrears began to accumulate, and at the present time this sewage farm is paying little or no dividend, and never will until the land can be had at the originally reasonable rate. It is a serious error, and one calculated to very much retard the progress of sewage irrigation, to imagine that a sewage farm can pay a higher average rent than one farmed in the ordinary manner. On the contrary, unless with a large amount of good luck, it will not afford a high rent. The influence of a wet season is felt with much greater severity on a sewage farm than on any other. Unless in a place of so exceptional a character as Barking, the sewage must be taken regularly and applied to the land wet or dry. If the rain should turn the fields into an absolute swamp, still the sewage must go over them, or some of them. The outlay required to bring a sewage farm into a proper condition suitable for the reception of the sewage, and capable of benefiting by its application, is a heavy and a serious item in the expenditure. The maintenance also is of a more expensive character than in the case of ordinary farms. It is of a more scientific nature, and demands a far higher amount of skill and knowledge on the part of those who have the management of the affair. If, with all these drawbacks, a heavy rent for the land be incurred as well, it is too much to expect that a sewage farm will pay.

There is another consideration which very materially affects this question. It is the price paid for the sewage, which in some instances has been excessive, and totally disproportionate to its actual manurial value. The strength of sewage varies very considerably, depending among other conditions upon the water supply, the description of town whence it is derived, and the system of sewerage and drainage adopted in each particular case. The truth is that both landowners and sewage owners, the latter of whom are generally local boards, expect to make a large profit out of a project which, although it has given undoubted evidence of possible success, is yet to a great degree experimental and under trial. While sewage farms have been in cultivation for some years, and a certain amount of valuable information and experience has accrued from them, yet the

principle has not become popularized. It is not too much to assert that not one farmer in a thousand would know how to manage a sewage farm as it ought to be. Some have tried it and failed, but failures of this description cannot be set down against the soundness of the principle, nor the conclusion deduced from them that sewage farms will not pay. Independently of the question of competency on the part of those engaged in the management of a sewage farm, that of proprietorship is an important consideration. It is said, "Every Englishman thinks he can farm." It is unnecessary to comment upon the number who have, to their cost, personally found this to be a delusion with regard to ordinary farming. The idea will be found equally delusive with respect to sewage farming, Local boards as a rule are, and always will be, found to be unsuccessful sewage farmers. The most successful farmer is the man who has a direct interest in the land and the produce, and gives personal and unremitting attention to them. There is very little doubt that the cause of some of the irrigation failures may be traced, not only to the incompetency of the so-called sewage farmers, but to the notion that the sewage would do everything itself. It was regarded by some as a miraculous fertilizer; it was only necessary to apply it to the land, and it would do its own farming. But the fact is, that any one who expects to manage a sewage farm with profit must have an intimate knowledge of all the details of ordinary farming operations. He must be a thorough farmer in every sense of the term, with the addition of the knowledge and skill requisite for the particular service he is engaged in. Playing at farming is a very losing game indeed, although people are loth to admit it.

The subject of markets is one intimately connected with the success of a sewage farm. Unless there are means available for disposing promptly and regularly of the produce at a fair price, the farm will not pay. So far as the grass is concerned, that can always be sold, and also most profitably, on the land itself; but the root and other crops for the most part must be sent to market. Here a good deal of practical knowledge is necessary, both with regard to the selection of crops and the time at which to send them. Tons upon tons of root crops which have been cut at the wrong time and sent to market, only to find it overstocked, have been sold for a mere trifle. We can call to mind one case, in which a large supply of red cabbage was dispatched to a market in which there was a glut of that vegetable, while there was not a single green one to be had. A knowledge of this fact at the farm would have made a considerable difference in the pecuniary results of that day's consignment. While the points to which we have referred in our present article prove beyond doubt that sewage farming requires no ordinary amount of skill, technical knowledge, and practical ability, to make it prove remunerative, yet we see no valid reason why it should not pay, provided certain conditions, which are indispensable, obtain. The rent must be moderate, the price paid for the sewage low, and under some circumstances none at all, and moreover the matter must be regarded by all parties in a proper light. In other words, the utilization of sewage by its application to land must be considered as a great sanitary utilitarian measure, and not as a speculative project which is to pay enormous dividends and enrich everyone connected with it. This it will never do, but, on the other hand, sewage farms, under proper treatment, will return a safe and fair percentage for all capital expended upon them.

## THE MANUFACTURE OF IRON AND STEEL RAILS.

By JOHN B PEARSE, Superintendent of Pennsylvania Steel Works.

Transactions of the American Institute of Mining Engineers.

In order to get an idea as to the strength of steel rails, it will be well to review the tests to which iron rails have been subjected. In England, Mr. Ashcroft found that the best 80 lb. rails broke under a 300 lb. weight, falling 15 feet. In Germany the Society of Railway Managers determined on and have long applied a test of 1,000 lbs. falling 10½ feet, as the standard which all first-class iron rails must reach. In this country no inspection nor test is applied, but tests made

show that iron rails from our most reliable makers, break under a six foot fall of a 1500 lb. drop as an extreme test, most of those tested breaking under a far less test; some breaking with less than a three foot fall of the same weight.

Everywhere where steel has been used, engineers have come to the conclusion that some test is required to show the regularity and strength of the product. As compared with iron, the tests which steel will stand are wonderful. After numerous experiments partially based on the experience of the rail-mill at Graz, belonging to the Southern Railway of Austria, the Society of German Railway Managers fixed upon a test of 2,000 lbs. falling 13½ feet. They found that this test represented the steel which suited their necessities, and also found that with steel of otherwise average purity, this test represented about one-half per cent. of carbon, and made it a rule to take no steel containing under three-tenths of a per cent. of carbon, because it was too soft. They expressed a hope that a harder steel could soon be made tough enough to stand the same test. In England, a test was adopted of 2,240 lbs., falling 15 to 17 feet on the rail on heavy bearings. This test has been found satisfactory under heavy traffic on average road-beds, and has been invariably retained by English makers, and adopted by American makers. It is an expeditious practical way of ascertaining the qualities of the rail. Experiment in Germany and experience in England pointed out the test corresponding to the proper grade of steel, and the test adopted has been considered the most practical one. The jar from a moderate weight (2,240 pounds), falling from a great height, is more sudden than that imparted by a heavy weight falling a small distance, and better adapted to exhibit the toughness of the rail. This latter is the object had in view in all tests, as it would take far too long a time to determine the quality of rails by a treatment approximately similar to that received in the track. An objection of some force has been urged against the English method of obtaining test pieces. They take one rail from each day's rolling, to indicate the quality of the rest. In this way their test becomes a matter of chance, and nothing they have yet done removed this character. Our American practice has been to test every charge, thereby insuring beyond doubt the quality of the rails.

After a short experience with steel rails it was found that their homogeneity is their distinguishing characteristic; but they unite entire homogeneity with considerable hardness as compared with iron. There are no layers to peel off, no welds to open out, the ends of the rails do not broom out as iron rails do, and the head wears uniformly along its whole length. Not only is the single rail entirely homogeneous, but all the rails made from a single charge have exactly the same qualities. Many experiments on the steel at Seraing, in Belgium, in Austria, and in this country, before and after its conversion into rails, show this to be a fact.

But the hardness is a most important point as regards wear. Some first-rate English rails have been found too soft for roads with heavy traffic. Therefore, a rail is wanted which will be hard enough to stand abrasion and wear, but strong enough to stand all the strains to which it is liable. The railroad engineer's idea of hardness is that quality which imparts durability without brittleness. Hardness is sometimes erroneously associated with brittleness because some hard bodies are brittle, but in steel brittleness arises from causes entirely different from those which produce hardness. The steelmaker's idea of hardness is a composite one—one that results from considering the effects of physical structure or grain of the steel, and the effects of carbon, phosphorus, and manganese. The effects produced by the presence of these elements far exceed any brought about by change of physical structure. Phosphorus and manganese occasion brittleness, while carbon in excess is seldom present, as the processes through which the rail passes have a constant tendency to reduce it. The state in which carbon is present in the rail is, however, remarkably influenced by mechanical treatment and the resulting physical structure. Those modes of reduction which work quickly and forcibly exert a strong influence to retain the carbon in a combined state, while the slower methods, on the contrary, permit some of the carbon to separate as graphite. These facts have been observed by Gruner and Caron, and have been corroborated in Austrian practice, as the following analyses of steel will show:

(*a*) Steel made for heads of steel rails at

Graz, and rolled into shape without hammering:

| | |
|---|---|
| Combined carbon | 03.8 |
| Graphite | 0.65 |
| Silicium | 0.05 |
| Manganese | 0.07 |
| Sulphur | 0.05 |
| Copper | 0.08 |
| Iron | 98.57 |
| | 99.85 |

(*b*) Steel made at Neuberg and hammered into shape:

| | |
|---|---|
| Combined carbon | 0.284 |
| Graphite | none |
| Silicium | 0.033 |
| Phosphorus | 0.044 |
| Sulphur | traces |
| Manganese | 0 139 |
| Copper | 0.105 |
| Iron | 99.445 |
| | 100. |

Both these steels were soft Bessemer steel, and from observation I made at the two works on the respective quality of their metal, I see no reason to doubt their correctness. A remarkable point in the matter is that the iron at Neuberg was much more graphitic than that used at Graz. At Neuberg they tapped direct from the blast furnace, and their "blows" averaged about thirty minutes, some running up to fifty minutes. At Graz they remelted their iron in an air furnace, and their "blows" were much shorter. The iron each works used was then of substantially the same character, made by charcoal from spathic ore. Neuberg made its own iron, while Graz bought its own iron largely from Mariazell and Eisenerz, furnaces not far from Neuberg.

Now, at the Pennsylvania Steel-Works, we have a quite graphitic mixture for conversion, but we find scarcely any graphite at all in the rails—in fact none. Out of many tests we have only one, an apparently abnormal one, in which the graphite amounted to 0.08 per cent., it being generally present in too small quantities to be estimated.

Speaking within the limits of steel manufacture, it is safe to say that brittleness has nothing to do with the mechanical treatment, yet by this treatment the state of the carbon may be controlled and the specific gravity and consequent density of the steel increased. Rails are brittle when too cold-short from the presence of phosphorus and manganese. The proper proportion of the former forms the most delicate point in steel-making, and must always be kept within safe limits. No good steel rail has ever yet been made with more than one-fifth of one per cent. of phosphorus, and half that is considered too much by Bessemer. In regard to manganese, our experience is not yet fully ripe. Its action, however, is far less dangerous than that of phosphorus, and in small quantities is beneficial.

We have thus a definite idea of the important qualities of steel rails and the proper tests to show their uniformity. The tests made on the steel preclude possibility of brittle steel being used, and it is evident that those methods of reduction which unite the greatest hardness with the necessary strength are to be preferred. In general terms, a steel rail is wanted to last a lifetime, and to be strong enough to stand all accidents of wear.

Railmaking begins with the Bessemer ingot. This is a block of highly crystalline metal, the tensile strength of which is low, and which contains some blow-holes or bubbles formed by the carbonic oxide retained by the liquid steel. The inner surface of these bubbles is generally oxidized, and they are apt to be more numerous near the surface of the ingot.

The first steel rails made ten years ago were treated like cast-steel. Until 1863 they were made from ingots seven to eight inches square and four and a half feet long in four heats. In the first two heats the ingot was hammered down to size, one end at a time, and swaged in dies to the shape of the first pass of the rolls. Then the bloom, by this time eight feet long, was rolled in two heats through twelve passes into a finished rail.

This process was excessively crude, wasting everything a steel-maker cares to save, and as the rails were found deficient and their weak points tested, it was found that the small size of the ingots and the little work done on them caused a great number of imperfect rails and a very poor quality in the steel. At this time the expressions of want of confidence in Bessemer steel took shape. We have now, however, surmounted all difficulties, and produced a reliable uniform quality of steel in enormous quantities considered in the

light of former capabilities of production. We now use very large ingots, which necessitate thrice the work formerly applied. In 1867 the ingots were raised in England to ten inches square, and in 1870 to twelve inches square, which is the size in general use. In America we have had exactly the English experience with small ingots, the efforts to use them to advantage having entirely failed.

Seeing, then, that large ingots weighing three quarters of a ton, and making two rails, have been found necessary, it has become a question as to what mode of working them up gives the best results. I think that hammering furnishes the preferable product, and my present experience goes to justify the opinion. Rolling is preferred by some makers because it is thought cheaper, but I think the better wear of a hammered rail is a strong point in its favor. Rolled rails are generally softer than hammered rails, for the reason I have given, namely, because their carbon is apt to be partially separated as graphite, and their density is less.

There have been, in the history of iron metallurgy, two noted contests between rolling and hammering, in one of which the hammer came off victorious, in the other the rolls. I refer to the manufacture of hammered iron and to that of armor plates. Hammered iron is a necessity for smith work, and the qualities imparted to it by continued piling and hammering are wonderful as compared with ordinary iron. The reputation of the Low-Moor and Yorkshire iron tires and plates is world-wide, and the steel tyre had in the Low-Moor tire for some time a formidable competitor. In this case the benefits are produced by a better texture of the iron and greater ductility developed by the work done. The cinder is thoroughly expelled in the blooming and first piling, and may be left out of the question. In the other case the object was to get as soft and wax-like an armor plate as was consistent with the strength necessary to resist the impact of the shot. As the work done by the shot generally used represents in foot-pounds the effect of one (gross) ton falling a mile and a half, it will readily be acknowledged that there is little similarity between the case of an armor plate and a steel rail, which has to stand a ton weight falling only 17 feet.

In my own experiments on the effects of the two processes, I compared ingots of the same steel with an average area of respectively about 75 and 110 square inches, average section, as they were the only moulds I had at the time to compare. I found that the rails made of blooms, hammered from the ingots of the latter section, stood over 100 per cent. more than the rails made direct from the ingot. The bloom was hammered to the size of the ingot, and each rolled in two heats, one of them a wash heat, into the same kind of rails. I tested in this way 31 different charges. Weight used was 2,000 lbs., bearings two feet apart. The rails from ingots stood 21½ feet fall of this weight, showing $1\frac{6}{10}$ of an inch deflection without breaking. The rails from the blooms stood a 43 foot fall of the same weight without breaking, and showed a deflection of $3\frac{1}{10}$ inches. This leaves a surplus of 50 per cent. in favor of the hammered rail, deducting 50 per cent. for amount due to difference of area of ingots. To show the connection, on a manufacturing scale, of these tests with the actual result, I would remark that we made 13,285 rails out of the ingots of 75 square inches average area. Of these there were rejected by the railroad, for insufficient strength after delivery, 178 rails, or 1½ per cent. Of the larger ingots we had made up to the fall of 1870, 34,320 rails, and had rejected for all causes, after delivery, only 18 rails, or $\frac{1}{10}$ of one per cent., or a quantity only $\frac{1}{17}$ as large as before.

We, therefore, continued to hammer, but now use an average section of 150 square inches; doing two-thirds the work under the hammer, and only one-third in the rolls. Our rails thus produced stand a ton weight falling 17½ feet, and leave an ample margin of reserved strength. We have had recent tests, in which the rail stood what was equivalent to a ton weight falling 70 feet without breaking, but have not yet got up to the armor-plate standard of a mile and a half. Out of a lot of 1,200 tons of 58 and 60 lb. rails, not a single rail, out of the 439 tests given, broke under a ton weight falling 16½ feet. We have since had many similar series.

The bubbles in the ingots give some trouble in the subsequent working, sometimes occasioning cracks in the ingot requiring to be chipped out. This we do, as we hammer the ingot down, without hindering the hammer in its work. Rolls are apt to laminate these bubbles instead of forcibly compressing them like the hammer, and it

sometimes happens that the bubble breaks out on the surface of the bloom, and causes a long streak where the metal is not sound. These streaks are especially noticeable in the head of the rail. In order to obviate the cracks resulting from these blowholes, a hammer must be associated with the rolls to chip out bad places; and this renders the rolling process more complicated than it would appear at first sight. I do not see why it is not simpler to do all the work under one tool, namely, the hammer.

The objections to hammering, on the score of cutting sharply into the metal, are not, in my opinion, of weight, as our experience agrees with the English, that you can hardly have too heavy a hammer for steel. We can strike two full blows of a 12-ton hammer on the same place without deforming or injuring the bloom in any way, or making a mark on it deeper than $\frac{3}{8}$ inch each time. As showing what steel will stand, I will say that I have seen, in Vienna, Haswell's hydraulic press reducing ingots from 10 inches thick to two inches at one squeeze, without injuring the steel, which was from Neuberg. It is thus surely idle to talk of a hammer as injuring steel in any way. The stroke of a heavy hammer works uniformly through the bloom, drawing the interior as much as the surface. We want to make a hard and tenacious bloom, and the concentrated blow of a heavy hammer is well adapted to that end. We lose practically nothing in ductility as compared with the rolls, and have ample room within the limits of our strength. The chemical composition controls the brittleness of our rails, and as long as we keep that right, we can make a comparatively hard rail well adapted to wear.

In regard to the amount produced by the two methods in the same time, the hammer compares very favorably with the rolls. A blooming-mill turns out about 55 tons of blooms a day from ingots. We do as much as that daily under a 12-ton hammer, and have done much more than that for a considerable time, so that the relative capacity of the two is hardly decided as yet. In five to six minutes we can hammer down, chip, and cut in two, and carry away, a large ingot, reducing it to one-third its former size; and in thirty-five to forty minutes do the whole work of getting a heat of five ingots hammered complete into finished rail-blooms, requiring no subsequent hand-chipping. For three months this hammer did an average of about 70 tons of rail-blooms per day, turning them out sound and well chipped.

As a matter of interest, it may be well to refer to the fact, that at Neuberg, in Styria, they use a 19-ton hammer on steel, and according to published statements, produce under it in a week only 65 tons out of two furnaces in 11½ turns. They hope, by using four furnaces, to get up to 130 tons a week. It shows well the spirit of American work to compare our product with this. We do now over three times as much as they hope to do, and do it under a hammer of under two-thirds the weight. The weight of ingots is about the same.

I have explained above my reasons for preferring hammered rails, all derived from experience capable of easy verification. In practice we have found, as far as we could compare hammered with rolled rails, that the former stand the treatment they have to suffer better than the rolled rails. From experience with rails of different making, rolled and hammered from ingots of the same size, I am enabled to say that the hammered ones have far less rejections on all accounts than the rolled ones, and that their strength against sudden jar is greater.

I believe, therefore, that the hammered rails are superior to the rolled in very important characteristics. I do not deny that rolling may be improved so as to equal a hammered rail. That is not impossible, nor improbable. It has not done it yet, in my opinion, but when it does, I shall be most happy to change my opinion.

In order to show the relative endurance of iron and steel rails, I would like to mention a case that may be regarded as furnishing an American experience of steel rails, equalling that had on the English railroads, and especially on the London and Northwestern. The Philadelphia, Wilmington, and Baltimore Railroad laid, in their yard in Philadelphia, steel rails on one side of the track, and iron rails on the other. The steel rails were hammered rails, and were, with the iron, laid in 1864. The steel rails wore out some 17 sets of the iron rails, and then the company stopped the experiment, laying steel on both sides.

On a curve of 525 feet radius, steel

rails have lasted intact since 1865, and are as perfect as when laid, where iron rails had before lasted only from three to six months.

None of the rails of the Pennsylvania Steel Company, nor of any other company in this country, have ever been worn out by traffic or shifting work, so that, after a five years' experience of American makes, I have reason to believe they will last at least a generation, under the hardest service.

## DIRECT PROCESSES.

By CHARLES M. DUPUY, C. E.

The great wealth of magnetic ores in this country is exceptional throughout the world. While they are of surpassing richness—almost pure iron—we work them into metal at a high cost for labor, and at a great waste of fuel and ore.

It is curious to note the slow development of any art, more particularly the manufacture of iron, surrounded as it is with so many real difficulties, and hedged about by so many firmly rooted prejudices.

Iron ore is mainly a compound of oxygen gas, earthy matter, and metallic iron. Almost the whole theory of reduction of rich ores is to volatilize oxygen, for the earthy matter may be nearly all washed out before heat is applied. Oxygen is the arch-enemy. In well-washed magnetic ore as usually prepared for the forge fires, nearly one-third, by weight, is oxygen, and the entire remaining two-thirds is metallic iron.

Carbon in its various forms, *par excellence*, is the reducing agent. At the required heat, the oxygen in the ore, having a greater affinity for the carbon, leaves the ore, and passes off as carbonic oxide. *The most perfect system of reduction consists in bringing ore, carbon, and heat together, in the most exact and economical proportions.*

The earliest process, practiced by the ancients, and still largely in use to this day, is the forge-fire, Catalan forge, or bloomery in its various forms. Here, rich ore mingled with charcoal, is subjected to a blast in a furnace, resembling a large blacksmith's forge, until reduction is effected. On the theory that oxygen will leave the ore when heated, and unite with carbon, the forge-fire method at first glance would seem to be a perfect process. This, however, is not the case. While reduction is in progress, and until the last atom of oxygen has left the ore, it is always ready to seize with avidity any "*free oxygen*" it may find in the blast, or draw from the surrounding atmosphere. It is this "*free oxygen*" which so largely consumes the fuel and is the means of melting down a large proportion of ore to a useless cinder. It causes a consumption of 300 to 500 bushels of charcoal, and over two tons of washed or separated magnetic ore to the ton of iron, whereas, less that one hundred bushels of the former, and less than a ton and a half of the latter, would be quite sufficient, could these objectionable features be removed. Another objectionable feature to the forge-fire is want of uniformity of product. That part of the bloom formed nearest the blast is semi-steel, while that farthest away is soft iron.

Fredrick Overman, in his little work on steel, says we want purer iron. "The immense ore beds of New York, New Jersey, Missouri and Wisconsin, as well as of other States, are unsurpassed in purity, and should produce iron equal to the best Swedish, and at a much cheaper rate than it can be imported. Ours are peculiar conditions, and resemble those of no other people. We should not copy the processes of other nations, but work out our own method in our own way."

The immense deposits of rich cinder from the forge fires which had been accumulating in England since the conquest by the Romans, finally suggested the invention of the blast furnace to work them up. It was soon found useful to smelt the lean ores, which abound so largely throughout Europe, and although the invention dates back three hundred years with comparatively but few improvements, the blast furnace still continues the great right hand of the iron master.

The facility of melting down large quantities of crude material, so as to separate the metal from its grosser impurities, in large and continuous operations, was certainly a great step to keep pace with the

rapidly increasing wants of an iron age. Still, while the blast-furnace frees the metal from its oxygen, and separates by specific gravity a large portion of its earthy impurity, it is by no means a perfect instrument for the manufacture of superior *wrought iron*. Owing to the variation in the atmosphere, and other uncontrollable causes, the run of a blast-furnace, from day to day, not unfrequently is wanting in uniformity, and, besides, is always charged and intimately incorporated with four to five per cent. of carbon. This carbon clings more tenaciously to the iron than the oxygen did to the ore, for the ore parted with its oxygen at a red heat, but pig-metal must a second time be melted, and skilfully manipulated for nearly two hours, before it gives up its carbon. It is true that the second melting, although involving high cost for fuel, labor and waste, separates quite perfectly the earthy impurities which may have remained; yet the fact that the forge-fire can exist, and that its product is so largely in demand at a much higher price, and for purposes that puddled iron can not supply, is conclusive proof that blast-furnaces do not fill up the need for a certain high quality of metal, which can only be produced by a direct method. The truth probably is, the blast-furnace is best adapted to working the lean, while a better direct method should be adopted for the rich ores.

The vast deposits of rich ores, yielding from 60 to 70 per cent. metallic iron, have long demanded a better system of reduction. During the past half century, various expedients have been suggested. One proposed to subject ore with carbon to heat in clay crucibles, until reduction takes place, then to empty and hammer the product, but it was found the iron adhered to and became incorporated with the crucible, causing waste of the former and destruction of the latter. Another suggested ore with carbon, heated in gas retorts. Gas retorts were tried, but were too perishable to be found useful. Another proposed heated vertical tubes, or retorts of fire-bricks; these, like the gas retorts, were too soon destroyed by a deoxidizing heat to be practical. Still another aimed to deoxidize ore with carbon, on fire-brick tables, which were heated above and below. The sensitiveness of the ore to the absorption of oxygen found floating in the furnace failed to secure a perfect deoxidization, and this plan was rejected. All these, and many other processes, although at times producing iron of superior quality, were not found economical. They have had their day of experiment and abandonment, and still a better direct method than the forge fire is demanded.

The ore seems to require a continuous reducing heat, from the time it is placed with carbon for deoxidization until it is reduced and consolidated to iron. Carbon will not act efficiently in withdrawing oxygen from the ore, if it can find "*free oxygen*" in the furnace. Such is the affinity of ore for oxygen, that however well the deoxidizing process may be progressing, if at any stage, until it is completed, the heat is changed from a "reducing" to an "oxidizing" heat, success is measurably defeated, and waste the result.

The whole aim should be to continue a reducing heat in the furnace until the ore shall be *thoroughly penetrated through by it*, at the same time to *shield both* ore and carbon by a *suitable covering from any free oxygen*, until it is not only reduced, but consolidated to metals. Whatever earthy impurity may remain in the ore after cleansing, and before the application of heat, is readily removed by the high heat required to weld the particles of reduced metal together. At this heat the earthy impurity is liquefied, and is compressed from the porous mass of iron, under the hammer, as water is squeezed from a sponge.

The elder Mushet—the father of iron experimentalists—observed the wastefulness of its manufacture, both in the forge fire and blast furnace, and spent his long and useful life in the improvement of iron. Among various other experiments, as early as 1794, he mingled ore and carbon in a crucible, and subjected it to a heat which reduced the ore and welded its particles together. At the same heat, after breaking the crucible, he was delighted to be able to hammer its contents into a solid bar of iron. Here was the real starting point of all the direct processes. The containing vessels, retorts, chambers or crucibles of various shapes and sizes, which since that time have been the subject of so many costly experiments and disappointments, must necessarily be of considerable thickness, to withstand, for a single operation, a heat sufficient to penetrate from the outside the few inches in thickness of ore and carbon lying dormant within them. A heat energetic enough to produce a thorough deoxidation in a reasonable time,

practically, is too destructive and costly of crucibles to be made profitable. To prevent this damage, a moderate temperature, reaching over a longer period, has been tested, but a moderate heat only partially deoxidizes the ore; it requires a high temperature to accomplish deoxidation thoroughly, and with sufficient energy. Beside this, the newly made metal is left in a porous, spongy condition, and is peculiarly sensitive to the furnace gases. It will receive a varnish of fresh oxygen over the innumerable little surfaces of its cells or pores or fibres, not only while exposed in that condition in the furnace, but still more the moment it is cooled and penetrated by the pressure of the atmosphere, just as every bar of iron, after cooling, receives a scale of oxygen on its surface.

To prevent this attack of the atmosphere, the hot, spongy iron, without external exposure, was at once dropped into the balling or reverberatory furnace. Still the waste proved excessive. This may be satisfactorily explained. While a portion of the oxygen, thrown into the furnace, unites with the carbon to supply a welding heat, *another portion penetrates to the infinitesimal surfaces of the pores or fibres of spongy metal, and these combined surfaces, so oxidized, are of such large extent as to cause great waste.*

The aim, then, was to close these pores, so as to prevent the penetration of furnace gases, by pressing the cooled sponge into blooms with hydraulic power, previous to the second heat. If the ore could have been thoroughly deoxidized at first, by the application of sufficient heat around the crucible, and if the surfaces of the pores had not been varnished with oxygen, on exposure to the atmosphere, as explained, this step might have been successful, but the small yield and rich cinder still pointed to a defect.

We may pass by all that class of processes for working ores to metal at one operation, on a series of tables or shelves, in a reverberatory furnace. The most prominent of this class is Harvey's process, on which large sums were fruitlessly expended for a number of years. They have not been successful, because the oxygen of the furnace is quite as ready to penetrate the cells of the partially reduced and exposed ore as it is to unite with carbon to support combustion. For a like reason all furnaces, either rotating or fixed, with the flame passing through them, and coming in contact with the ore, cannot be the most effective.

For a time there was a process which was thought to promise success, because the deleterious furnace gases were excluded throughout the operation. The ore was packed with carbon, in alternate layers in a steel converting furnace, to the extent of 40 or 50 tons, and gradually heated from the outside, up to the welding point. In a couple of weeks the metal, thoroughly reduced and consolidated, was removed in a cool state to the balling furnace. The maintenance of this converting furnace up to a high heat for repeated operations would of itself have defeated this process, had there not been a more serious difficulty. The ore, it is true, was thoroughly reduced, but was more or less carbonized, up to the condition of cast iron, but the process was too expensive, for the manufacture of pig iron it could never have successfully rivalled the blast furnace.

In following out these various devices, they were thought to be fairly based for success on the exact results from covered crucible in the laboratory, and in keeping with the blast furnace and forge-fire operations. In the laboratory, the heat applied outside of the closed crucible brings all the metal either to cast or wrought iron, at pleasure, by properly proportioning the carbon, because no external oxygen can interfere. Deep down and between the thick walls of the blast furnace crucible in like manner all atmosphere is excluded, and the large excess of carbon it contains thoroughly decomposes the oxygen of the blast. In it the high heat required for perfect deoxidization is maintained, and the metal, saturated to a high degree with carbon by the powerful blast pressure, is nearly all saved as a carburet or pig iron. The shallow forge fire, with a light blast, certainly produces wrought iron in a few hours, but with great waste of fuel and ore, which is accounted for by the penetration of the atmosphere.

Experience proves that it is clearly impossible to impart sufficient heat from the outside of a chamber or crucible to accomplish practically, on a large working scale, the results reached by laboratory experiments in the chemist's crucible. Nor can a high column of ore be uniformly penetrated by a blast of reducing gases forced through the mass. As in the German "Stuck" or "Wulf's" oven, the blast

pressure necessary to penetrate to the top a high column of ore, at every operation, will produce a mixture of cast iron, steel and wrought iron, of grades varying from the base upward. A low column of ore will have the atmospheric objections of the forge fire. It is, further, impossible to maintain a welding heat in the ordinary reverberatory furnace without having the delicate fibres of partially reduced ore largely destroyed by the deleterious gases to which they will be more or less exposed.

To ensure an economical, direct method, the operation must not pause with the production of spongy iron. As in the chemist's closed crucible, or in the blast furnace or forge fire, the process must go on with a continuously increasing heat, until the cells and fibres, produced by the withdrawal of oxygen from the ore, *are compressed* together *and solidified into a cake, at the pasty condition of the metal.* It is then a commercial product of wrought iron, either hammered or otherwise.

How shall this be accomplished? Some years since the writer suggested that rich ores, mingled with the proper proportion of carbon for reduction, should be placed in thin sheet iron cases, of size most convenient to handle. Many of these canisters of ore, to the extent of several tons, placed in a simple, cheap furnace, of a peculiar device, in a few hours will become caked and solidified to wrought iron without further labor, while the encasement will be preserved to the end, the whole to be hammered into a bloom or bar at the same heat.

Deoxidization commences immediately on the introduction of the canister into the furnace, as proved by the blazing of carbonic oxide from them, which continues without intermission until reduction is completed. The heat, which is gradually absorbed, increases in intensity until reduction is effected, and the particles of iron are pasted or mated together; then canister and contents being withdrawn, are welded together in any of the ways puddle ball is usually treated.

The sheet iron canister or crucible will cost from $5 to $6 to the ton of iron produced. It is a convenient, portable package, keeping the particles of ore in close contact with the exact proportion of carbon required for reduction. It allows the heat to penetrate readily on all sides. It is homogeneous with the new metal, and welds up with it under the hammer. Above all, as it *shields and protects the ore from the blast and furnace gases during the whole operation of deoxidation and consolidation, the metal is of superior quality,* and is *nearly all saved.* A series of experiments, extending over many years, confirms the writer in the belief that this process solves the problem of the manufacture of wrought iron direct from the natural oxides, on any scale of magnitude, and at a cost, both for plant and manufacture, which will effect a great saving over the indirect method. The results of these experiments, in the form of samples of metal taken at all stages of the process, are open to the inspection of any one interested in this subject.

## FURNACES AND THEIR CONSTRUCTION AND MANAGEMENT.*

By M. CHARLES FAIRBAIRN.

"The Engineer."

Within the last two or three years a great change has taken place in the conditions under which our manufacturing supremacy has been maintained, and, whether we bleieve the unpalatable fact or not, there is not the slightest doubt that the sudden and rapid increase in the price of materials and labor has tended to place us more in a position of equality with competitors whom we were wont to overlook and despise. The change came too suddenly upon us, and has been too sweeping and arbitrary in so short a time, inasmuch as the necessary improvements in labor-saving machinery and its introduction could not be attempted, far less completed, in substitution of manual labor and many expensive processes we have so long allowed ourselves to become habituated to. At the same time I believe that the revolution which has taken place will ultimately prove beneficial.

The change has to a great extent been secured by powerful combinations among

* Read before the Edinburgh and Leith Engineers' Society.

the industrial classes directed to one point, and whether that power has been judiciously applied is apart from our subject, except in so far as it has given a greater desire and more necessity for those improvements in machinery which at less cost and by more rapid production will inevitably reduce the prices of materials, which have been increased far beyond their normal value. In this sense the public are nearly always gainers in the course of time. It must be evident to every thinking mind that the arts and manufactures are every day becoming more intimate with and dependent on the severer sciences in a more recognized form, and that as we move onward in the career of improvement that connection becomes more and more intimate; and as the applied sciences derive their facts from experiment, and the deductions on which their utility depends belong to the province of abstract science, so in all departments of human industry and knowledge we are all mentally dependent—the chemist in his laboratory, the philosopher in his study, and the artisan at his bench, are all working towards one great end, acquiring new facts and adding to the sum of our experience.

The mutual assistance and aid rendered by this division of labor has probably stimulated the spirit of inquiry and discovery more forcibly from the unusual position in which we find ourselves placed with regard to the cost of materials and labor, because now when the pressure has come we begin to realize the truth that in many instances the fact of having an abundant and cheap supply has been the cause of apathetic indifference and reckless wastefulness. Accordingly we have failed in a great many instances to utilize our experience of the beneficial effects which improved machinery has conferred on us, in a great many of our manufactures, during the last half century; and if, as I believe, the unreasonable demands of labor have only stimulated us to more intense activity in the direction of improvement, it has accomplished more good indirectly than we are ready to admit at first sight.

Perhaps not any of the materials in use in our manufactures, and upon which our prosperity depends peculiarly, have been so much and so recklessly wasted as those great stores of fuel so providentially placed within our reach. It would almost seeem as if we were endeavoring to ascertain the truth of the fable of the goose that laid the golden egg, by killing our goose as hard as ever we can. It may or may not be true that our coal stores are being rapidly exhausted, but this much is certain, that every day brings that time nearer when our coal will be more expensive to get, and necessarily less of it; and we do not yet see our way to finding a substitute at anything like a reasonable costs. True we hear a great deal of nonsense talked about the decomposition of water supplying gas at a cheap rate, others suggest electro-dynamic engines; but so far as we know yet—and I am afraid so far as we are likely to know—there is no source of power at all approaching to coal for cheapness, and there does not appear any probability of heat engines ever being supplanted by electricity or galvanism, of which such costly material as zinc or other metals supplies the force.

Dr. Joule, in some experiments conducted some time ago, ascertained that a grain of zinc consumed in a galvanic battery generated sufficient power to raise 145.6 pounds one foot high. Now it has been proved that a grain of coal consumed by combustion exerted a power of nearly 1400 foot-pounds. This is nearly ten times the power given out by the zinc. It is said, however, that thermo-electric engines utilize the initial force supplied about four times better than heat engines, which would make a grain of zinc give about two-fifths of the power of a grain of coal. But zinc costs from forty to fifty times as much as coal, while it gives only two-fifths of the efficiency.

During a number of years I have been trying experiments with furnaces, with a view to the economy of fuel. As opportunity occurred, the furnaces I experimented on have been of various kinds, but lately they have been what are know as reverberatory furnaces, chiefly used for puddling and reheating iron. Before entering upon a description of the furnace I found to answer my purpose best, I will briefly desribe what a furnace should be, and how it should be constructed to answer all the conditions requisite for economy of fuel; and, secondly, our furnaces as at present constructed, and why they are so wasteful. The great variety of

kinds of fuel, although they contain nearly the same ingredients, but in different proportions, renders it a somewhat difficult task to define what a furnace should be. Hydrocarbons, such as pitch, tar, naphtha, and petroleum, have all to pass into the gaseous state before they can be burned.

Coke, which is coal with all the bituminous and gaseous portions taken out of it, is nearly pure carbon with a small proportion of ash.

Anthracite coal, which is very similar in its nature to coke, is almost wholly composed of free carbon. It is liable to split and fall into powder, it burns without flame, and with very little smoke, and requires a very strong draught.

Bituminous coal, again, of which there is an immense variety, has a smaller proportion of carbon with a mixture of hydrogen and oxygen. From this it will appear evident that special provision must be made for a supply of air to support combustion instead of the different kinds of fuel used. Thus, a furnace arranged for burning bituminous coal might be very wasteful in burning anthracite coal; due regard then must be paid in all cases to the character of the fuel employed. The indispensable conditions attached to a good furnace for all kinds of fuel are: [1] A good draught which can be regulated at will, so as to avoid forcing the fire too much; (2) a large and roomy combustion chamber surrounded by fire-bricks, and removed, if possible, from the place where the heat is to be used; (3) that the sides or walls of the furnace have at least two thicknesses of bricks nearest the fire, and an outer wall having an air space between of about three inches; (4) that the supply of air to the furnace can be regulated at will.

I do not think we can always command all these conditions, especially in a furnace constructed on the principle of depending on atmospheric pressure for draught; and the reason is obvious, because in order to maintain a good and equal draught we require not only a tall chimney, but the chimney must be maintained at a high temperature, about 600 deg; and as the temperature within the furnace may be assumed at 2500 deg., the abstraction of this large quantity of heat to keep the chimney at a sufficiently high temperature amounts to one-fourth of the heat, and consequently the fuel which is expended for this purpose alone. Nor is this the only drawback. The attendant on the furnace, who may, and often has other duties to perform, puts on a heavy load of coal. The flues and chimney are rapidly cooled, and the power of the draught reduced at the very time when it should be greatest. The second and third conditions mentioned may assist in getting over irregularity in the power of the draught to a certain extent—that is a large and roomy combustion chamber, and the sides constructed to prevent loss of heat. I do not suppose any person who has not had an opportunity of seeing a furnace in operation with the heat confined in the manner described could have believed the effect would be so powerful; the inner lining actually acquires a white heat, thus serving as an accumulator, which is given out again when the temperature of the fire is reduced (as in the case of a fresh charge of fuel), and at the same time assisting to bring the fresh fuel into active combustion more rapidly; the heat is again returned to the fire-bricks, and kept ready for future use.

Doctor Siemens has taken advantage of this idea, although in quite a different way, in his celebrated gas furnace; and as it has been very effective in economizing fuel in very large iron manufacturing establishments, I will try and describe it briefly here. A close furnace is constructed entirely of fire-brick, and capable of holding several tons of coal. The grate bars slope at an angle of 45 deg., so that the fuel as fast as it is consumed slides down on the top of the fire, making the furnace in a manner self-feeding. The fire is lighted from the bottom, and just enough air admitted to support a slow combustion. The small quantity of carbonic acid formed at the bars where the air gets free access is decomposed as it passes through the mass of incandescent fuel above, and taking up more carbon is converted into carbonic oxide. The products of combustion are carbonic oxide, hydrogen, and oxygen. These products are passed on through a pipe into a furnace, receiving on their way the requisite quantity of air, and becoming thoroughly mixed with it, are consumed in the furnace. The calorific effect of this furnace regarding the distribution of the heat developed has been investigated by Kraus, and may be condensed thus:

Amount of heat expended in the first process, 31.7 per cent. of theoretical effect of complete combustion, that is in obtaining the gases. Thus, heat lost in the chimney and in transmission from the gas-producing furnace to the gas-consuming furnace is about 23.86 per cent. leaving 76.14 per cent. to be utilized. Again, taking into account the loss—if we may call it so—of 31.7 per cent. In producing the gas, the total duty of the coal used, 52 per cent. and 48 per cent., represents the loss. This appears a very large percentage of loss, but when we take into consideration the enormous loss in the ordinary furnace this almost seems trifling by compari on. Of course this estimate takes the total or theoretical heat as contained in the coal. The Siemens furnace requires great care in its management, and is said to be more useful for heating large masses of iron for forgings or long bars than for puddling or the intricate processes of iron manufacture.

If I have been so fortunate as to make my description intelligible, it is clearly evident that this must be, and really is, a very economical furnace. None of the combustible gases can escape, and what is of very great importance is the exactness with which the air can be supplied. I have purposely omitted a great many details which those among you acquainted with the furnace will perceive, but I only wished to convey a general idea of its construction, and have introduced it here on account of its novelty and ingenuity. At the same time I by no means accept it as, in all respects, a model on which to construct furnaces, but it is celebrated as the best at the present time for some purposes.

Siemen's furnace, however suitable for large establishments where a great number of furnaces have to be supplied with gas, is clearly too cumbrous and costly for smaller places, and the question arises—can we not effect, approximately at least, a similar result in single furnaces to what is done by the Siemens furnaces? I think so.

We will now consider our furnaces as at present constructed, and why they are so wasteful. We hear a great deal about thin fires and regular charges in the ordinary furnace; and this is quite correct, inasmuch as it is the only way by which a right supply of air can be introduced to mix with and consume the gases. There are always two dangers we have to avoid. One is too much air, which is the least of the evils, and in which case a very large body of air passes away unconsumed, but it also carries away with it a certain amount of heat which cools the furnace and impedes the draught. The other evil of too little air is still more injurious, for the gases having only a small share of the oxygen required are burned into carbonic oxide, and this very often accounts for the deficient supply of steam from a boiler in consideration of the coal burned. But these fires are liable to burn into holes and admit streams of cold air; nor is this the only objection, for when the fire is fed with fresh coal, which must of necessity be very often, the new coal absorbs a large proportion of the heat of a thin fire, and immediately lowers the temperature. The fire contains a certain number of units of heat. If twice the quantity of coal was in active combustion there would be double the number of units of heat, and it could therefore more easily sustain the reduction of temperature following a fresh charge of coal. I imagine the distillation of gas from coal or volatilization is a process similar to steam carrying off the heat from boiling water. The coal at first becomes an absorbent of the heat and then liberates the gases, and the volatilization of the bituminous portion of the coal acts in a similar manner to the production of steam, as I have said. The process is one of the most energetic known in cooling, because there is so large a portion of the heat converted from the sensible to the latent state. Regarding the quantity of air required in the ordinary furnace for the combustion of coal, I suppose very few people have any idea of the magnitude of the demand. It is generally given as 300 cubic feet, or 24 lb. of air to 1lb. of coal. Let us place this in another light. In my own establishment in Gateshead I have seven furnaces, each of which uses about one ton of fuel per day, in all about seven tons; therefore $7 \times 24 = 168$ tons of air required. Again, a pound of coal requires about 300 cubic feet of air. If we imagine the 168 tons of air made into a long stream of one square foot in area, the total length will be 21,381 miles in length. Another great cause of the loss of heat, as before stated, is the quantity of heat continually passing away to the chimney. I have said that a furnace may be more efficient for one kind of fuel than another; but the principal causes of loss in the ordinary furnace I have stated

above, and which I will again enumerate here:—(1) Loss of coals in firing. The best coal is often small and very brittle, and in stirring the fire a large quantity falls through the spaces between the bars, more especially when there is a necessity for hard firing to promote combustion; (2) the loss from unconsumed gases passing away, being burned into carbonic oxide from want of the requisite quantity of air; (3) loss from too much air, either from the fire burning into holes and allowing the air to pass through, or absence of means for regulating its admission; (4) loss of heat by radiation through the walls of the furnace; (5) loss from the quantity of heat passing to the chimney. One difficulty—that is, regulating the supply of air to the furnace—can only be overcome by artificial means, either by a fan-blast or steam-jet. I believe the time is fast approaching when the supply of air to furnaces will be regulated in this way as the most efficient and economical, and as obviating a great many of the faults of our present furnace. The idea is old enough. However, the arrangement of furnace I will describe presently may or may not be new. I never saw it before, nor am I aware that anything of the same kind has been tried, and to it I have added a supply of air by means of a blower. In this furnace, of which the drawing is a longitudinal section, the coal is introduced from the top, and is always on the top of the incandescent fuel, at the side of the furnace furthest from the place where the flame makes its escape. The hearth is of fire-brick, and during the meal hours all the ashes and clinkers are removed by the hole in the side of the furnace. The area of the hearth is about two-thirds of the area that it was previously; the blast is introduced above the new coals, and passes through them. As the coals begin to ignite, all the inflammable gases are forced through the fire, and at the same time mixed with air. The advantages with this kind of furnace seem to be the following:—(1) The whole of the gaseous products are made available; (2) there is entire absence of smoke, in consequence of perfect combustion; (3) there is a smaller quantity of air required, probably about one-fourth less, that is, about 18 lb. to 1 lb. of coal; (4) no increase of temperature above the external air is required in the chimney, and the escaping heat from the furnace can be used for other purposes; (5) a higher temperature in the furnace, and more rapid circulation of heat; (6) the perfect control which the attendant has over the furnace as regards temperature, getting the fire lighted and into operation in less time, when they have not been in use. There is also another very important point in connection with this method of making reheating furnaces—that the air can be so nicely adjusted by means of the blast and damper as to insure that nearly all the oxygen will be taken up by the carbon and gases, in consequence of which the iron is heated with scarcely any loss from oxide or scale. The balance of pressure can be made so that even when there are unprotected inlets to the interior of the furnace, the flame can be made to come to the edge of the open space. I believe the efficiency of the furnace might be largely increased by using hot air, which might be done by passing it through pipes or brickwork placed in the flues; for if we have the heat of the furnace 2500 deg., and the entering air heated to 500 deg., the result would necessarily be a great saving. On this point we have the experience of blast furnaces as an indication of what might be saved by this means alone.

The application of this method of constructing furnaces is more difficult to existing steam boilers, and this we can only accomplish by constructing a separate combustion chamber, in which the gases could be properly ignited before passing below the boiler. There is no doubt that the furnaces of ordinary steam boilers are extremely faulty. A long tube of small diameter, in which the complicated processes of mixing the air with the combustible gases, of distilling these gases, and igniting them while they are hurried away over the surface of the plates of the boiler at high speed, cannot in any sense be made economical. In this case these fires are really indispensable, and while we have the cooling effect inseparable from the distillation of gas from coal, and then the cooling effect added of the flame coming in contact with the boiler which has to be heated. Dr. Ure says on this point, "When a boiler is set over a fire it should not be too near the grate, lest it refrigerate the flame and prevent that vivid combustion of the fuel so essential to the maximum production of heat by its means; and this is simply what we do. Marine boilers have all the faults enumerated above. There is,

however, more reason for their use in this manner, from the small space they are allowed to occupy for the work they have to do; but even in this class of boilers the principle of the blast might be introduced with advantage, if the furnaces were made a little larger in order to allow a thick layer of coal on the bars. There would be, of course, danger to the boiler either from a stream of flame or cold air being projected against the plates. Another cause of waste in marine boilers arises from the furnaces and tubes having to work a long time without being properly cleaned. My own experience in more than one of the large Atlantic steamers showed that on beginning a voyage with clean boilers the consumption of coal per indicated horse-power was about 5 lb. of coal; after ten days it had increased to 10½ lb. of coal per horse-power. I have mentioned a stream of cold air as being sometimes dangerous to a boiler. I will here give an example from my own experience. One of the forward furnaces about nine days after starting our voyage began leaking badly and put out the fire; we got it repaired in port, and some time after it gave way again at the same place, for some reason. We had shortened the lower bars in that furnace, and this brought the bridge forward nearer the mouth of the furnace; in the course of time the portion of the bridge above the bars got worn and sloping backwards. There was a windsail or ventilator in front of this furnace, which brought cold air down from above to the boiler-room; it struck me this was the cause of the mischief. When the men were cleaning the fire out—this is done every eight hours—the cold air rushing down the windsail entered the furnace with great velocity, having the impetus of its own force and the draught in the furnace, and striking against the bridge was deflected by the angular point against the plate in the furnace, or rather at the bend upwards from the furnace towards the tube plate, which by the violent contraction gave way."

I have again to mention that a furnace which will suit admirably for one kind of coal will not answer for another. Thus, the conditions under which coke and anthracite coal enter into combination with oxygen are much less complex than in burning bituminous coal, and the great point to be observed is that a large quantity be kept on the bars; there is not so much danger of the carbon passing away without its supply of oxygen—in fact it cannot do so, as it cannot rise until it has its quantity of oxygen to liberate it. In bituminous coal the bituminous portion is only serviceable for heat when converted into gas, while the carbonaceous portions are consumed only in the solid state, and they must be separated, as explained, before they can be consumed. Thus, when coke or anthracite coal are burned, the products are carbonic acid gas and nitrogen; while with coal we have carburetted hydrogen, nitrogen, and carbonic acid gas or oxide.

Again, to enable us to compare the quantities of heat in different substances, we are compelled to use some standard by means of which any quantity of heat may be measured, and the standard generally used is the thermal unit, or quantity of heat required to raise 1 lb. of water 1 deg. Fah. In algebraical formulæ this quantity is usually shown by the letter J, in honor of Dr. Joule, who discovered this unit of heat. Dr. Joule found by careful experiments that the power developed by the fall of a pound weight through 772 ft. will raise the temperature of a pound of water 1 deg., and this is called the mechanical equivalent of heat. The investigations of Messrs. Faber and Silberman regarding the total heat of combustion in thermal units are generally recognized as the standard now, and they have been condensed by the late Professor Rankine, of Glasgow, as follows: "The burning of carbon is always complete at first, that is to say, 1 lb. of carbon combines with 2⅔ lbs. of oxygen and makes 3⅔ lbs. of carbonic acid; and although the carbon is solid immediately before the combustion, it passes during the combustion into the gaseous state, and the carbonic acid is gaseous; this terminates the process. When the layer of carbon is not so thick, and the supply of oxygen is not so small but that oxygen in sufficient quantity can get access to all the solid carbon, the quantity of heat in thermal units is 14,500 to each pound of carbon. But in other cases, part of the solid carbon is not supplied directly with oxygen, but is first heated and then dissolved into the gaseous state by the hot carbonic acid gas from the other parts of the furnace. The 3⅔ lbs. of carbonic acid gas from 1 lb. of carbon are capable of dissolving an additional pound of carbon, making 4⅔ lbs. of carbonic oxide gas, and the volume of this gas is double of that of the carbonic acid gas which produces it.

In this case the heat produced, instead of being that due to the complete combustion of 1 lb. of carbon, which is as we have said = 14,500 units, falls to the amount due to the imperfect combustion of 2 lbs. of carbon burned to carbonic oxide; thus = 2. × 4 400, being the number of units of heat in carbonic oxide = 8,800 units, showing a loss of heat = 5,700 units, which disappears in volatilizing the second pound of carbon. Should the process stop here, as it does in furnaces badly supplied with air, the waste of fuel is very great, as the carbonic oxide has a large quantity of carbon in it which is dissipated in the air without any useful effect. But when the $4\frac{2}{3}$ lbs. of carbonic oxide gas, containing 2 lbs of carbon, is mixed with a sufficient supply of fresh air, it burns with a blue flame, combining with an additional $2\frac{2}{3}$ lbs. of oxygen, making $7\frac{1}{3}$ lbs. of carbonic acid gas, and giving additional heat of double the amount due to the combustion of $1\frac{1}{3}$ lb. of carbonic oxide; that is to say, 2 lbs. of carbonic oxide 10.100 × 2 = 20.200 units, to which being added the heat produced by the imperfect combustion of 2 lbs. of carbon, or 4.400 × 2 = 8,800, there is obtained the heat due to the complete combustion of 2 lbs. of carbon, or 14.500 × 2 = 29,000 units. Knowing the total number of thermal units in any combustible, we can soon ascertain the highest temperature that can be produced in the furnace with any kind of fuel; the products of combustion of coal being carbonic acid, nitrogen, steam and ashes. And if we take the means of the specific heat of these products, we find that they come very near the specific heat of the air. Again, as 12 lbs. of air will supply as much oxygen (supposing the whole of the oxygen to be taken up) as will be sufficient for the combustion of 1 lb. of carbon, the total weight will be 12 lbs. of air + 1 lb. of carbon = 13 lbs. Now the total heat of carbon we have seen is 14.500 units of heat, and the mean specific heat of the products of combustion is 0.238; thus this mean specific heat × 13 lb. of air = 3.094 and $\frac{14500}{3.094}$ gives 4691 deg.; this, however, is on the supposition that every atom of oxygen is used. If twice that quantity is used, as is usually the case, then the temperature will be 2437 deg. If we take a forced draught by fan or otherwise, by the same calculation we arrive at a temperature 3137 deg.

—the supply of air being 18 lb. to one pound of carbon. These figures are rather complicated to carry in the mind, and perhaps might have been dispensed with here. But there is one result we arrived at in their use we may follow a little further—we find that there are 14,500 units of heat in a pound of carbon, which if it could be all used in a steam engine would give stupendous power; we found that the unit of heat = 772 foot-pounds and 14,500 × 772 = 1,119,400 = or 339-horse power; and therefore, when we speak of a loss of about 60 per cent., we are left with 136-horse power; and as in the Seimens furnace he claims to save 40 per cent. on the latter, we arrive at 190-horse power from one pound of carbon. It is supposed that in some instances we have realized about 70 per cent. of the theoretical heat in fuel. This I would be inclined to doubt. We have seen that with the ordinary furnace we lose about 25 per cent. in getting a draught; we have to add to this loss from small coal, too much or too little air; the products of combustion flying off to the chimney at a speed of 30 ft. in a second in some instances, it must be abundantly clear that 50 per cent. of the heat of fuel we use is lost. It was stated not many weeks ago that, in some processes in connection with the manufacture of iron, the quantity of fuel used was sufficient to produce the desired result fourteen times if properly applied. I think it is clear we begin by placing the chimney at the wrong end of the furnace, and the air ought to be driven in, not drawn though. We have seen that when a blast is used we can have a pressure in the furnace sufficient to balance the pressure of the atmosphere. The waste heat could also be made to do work in passing away. I dare say most of us now present can recall instances to our mind where a number of furnaces are used, and where the heat of one, if it could be retained and applied, would be amply sufficient. The blast, then, is the only means of doing it, and I do not think the time is far distant when the hideous pillars we seem so fond of now will be no longer seen.

I have implied that the position in which we find ourselves with regard to the cost of the materials and labor will probably accomplish more in this direction than the mere intellectual activity of a few eminent men striving after greater perfection, because they will not be listened to until

penuriousness compels attention. Thomas Carlyle says very finely, "Alas! there is no possibility for poor Columbus now at any of the public offices, till once he becomes an actuality, and says, 'Here is the America I was telling you of.'" A hopeful sign, however, and one sure to have beneficent results, is the exhibition to be held in Manchester in a short time on this subject. There is indeed plenty of room for improvement; there is an abundance of facts on which to exert our reasoning powers, and ample space for experimental research. We want new ideas or thoughts, which, after all, govern the world. This is at least the lesson which our experience teaches as we grow older; and if with our progress we learn a wise humility, we will also learn that the more we know and acquire, the more our ignorance and dependence become apparent to ourselves. We learn also that, strive as we may, we never get beyond the border-land of knowledge, and that there are secrets beyond that boundary which will never be revealed on this side of the great change which awa ts us all.

## BLOWPIPE ANALYSIS.*

From "Iron."

Probably no one instrument is of more use to the thoroughly practical chemist and assayer than the blowpipe, and yet none is more unjustly neglected. It is a matter of common observation among those who watch students that they rush over the "preliminary examination" of the unkown substances given to them as exercises, with an unwise haste, anxious to reach what appears to them the real business of analysis. Many a time have we seen a judicious teacher check his careless pupils, and show them, with blowpipe, tube and charcoal, how they can ascertain not merely the road which they ought to follow in making a full analysis, but how, with these simple implements, they may learn in a few minutes almost as much as they need, in the majority of practical cases, about an unknown or commercial product. We by no means think that blowpipe analysis should be practised to the exclusion of the wet method; but we are strongly of opinion that it deserves a great deal more attention than it usually receives. A brief consideration of the development and present condition of this branch of chemistry will justify this opinion.

The blowpipe, in the common form still in use by braziers and other workers in metal, has been used in the arts for ages—possibly even by the ancient Egyptians. In the early part of the eighteenth century it appears first to have been employed for scientific purposes, by Anton von Swab, a Swedish mining director. He seems to have used the blowpipe for the discrimination of ores and minerals. His countryman Cronstedt, the mineralogist, was largely indebted to the blowpipe in erecting his chemical system of mineralogy, an account of which he published in 1758, and in von Engeström's English translation of this work appears a full account of Cronstedt's method of using the blowpipe, and of the behavior of minerals before the blowpipe flame, alone and with fluxes. Bergmann greatly extended the usefulness of the blowpipe by employing it in qualitative examinations of every kind. He proved that by the aid of this miniature furnace elements which had hitherto escaped detection by more formal methods could be easily discovered, and but for ill-health he might have done even more. His pupil Gahn carried on the work, and was so dexterous that by a simple examination of the newly-discovered mineral oxide of tantalum, he discovered that it contained less than 1 per cent. of tin. To Berzelius, however, we are indebted for the basis of the modern science of the blowpipe. Gahn did not record his experience, though he showed the greatest liberality in communicating his knowledge. He selected Berzelius as a favorite pupil, and to this eminent man we owe a work which was long the standard one upon the whole subject, and which may still be consulted with profit.

After Berzelius came Harkort, who established the practicability of employing the blowpipe in far more delicate work than had previously been attempted, or even

*"Plattner's Manual of Qualitative and Quantitative Analysis with the Blowpipe." From the last German edition, Revised and Enlarged. By Professor Th. Richter. Translated by Henry C. Cornwall, assisted by John H Caswell Second Edition, revised. (New York: D Van Nostrand: London: Sampson Low.) 1873.

conceived possible. Hitherto only qualitative determinations had been aimed at with the blowpipe. Harkort, in 1827, perfected a quantitative blowpipe assay of silver. His early death stopped his prosecution of this line of research; but Plattner proved himself a worthy successor, and we have in the work before us a compendium of almost all that is known of this important branch of practical chemistry. The book is truly Teutonic in its ponderousness, its minuteness of detail, and its comprehensiveness; but it is a worthy neighbor of Fresenius on our shelves, and calculated to be quite as useful. Possibly it may be somewhat too full—there is some evidence of this in a few places where the translators confess that they have not wholly followed the minute details of the original—but in a book of reference this is more pardonable than deficiency.

Perhaps our readers will obtain a better idea of the nature of this book if we refer in some detail to two or three selected sections. We must premise that the first 120 pages comprise a description of apparatus, manipulation, etc., and tables of reactions, in which we should like to have seen included, as closely related to the subject, the reactions with the Bunsen burner, recently described by Bunsen himself. Abstracts of these are, however, accessible in Mr. Vacher's last edition of Fresenius's "Qualitative Analysis," and in the "Owens College Junior Manual of Practical Chemistry." Two hundred and seventy pages are then occupied with an account of the behavior of minerals under the blowpipe, with instructions for not merely the detection of one or two components, but for their separation. This is useful information, though possibly none but a Plattner, Scheerer, or Richter would think of thus performing a detailed analysis. Upwards of a hundred pages are devoted to the description of quantitative blowpipe analysis, an appendix and two indexes completing the work. The fact that the index of minerals and metallurgical products described occupies twelve pages of small type, is proof enough of the comprehensive manner in which the subject is treated. An abstract of the sections relating to iron will confirm this, if confirmation is wanted. First is given a list of 120 minerals and metallurgical products in which iron occurs, described in brief detail, as for example:—"Chromite (chromic iron), ($FeO,CrO,MgO$)($Cr_2O_3,Fe_2O_3,Al_2O_3$), occasionally also containing a little $MnO$ and $SiO_2$; the amount of $FeO$ varies from 20 to 36 per cent." Then we have instructions for the examination for iron, which include the blowpipe characteristics of the minerals and metallurgical products before mentioned, and are divided under various headings. The mere detection of iron in any of its common salts is, of course, perfectly simple, the borax bead or the magnetic residue—each of which tells its story plainly—being easy to obtain. The difficulty is when some other element is present to mask the reactions. Cobalt may be taken in illustration, as the magnificent blue produced by its protoxide with borax completely overpowers the pale iron color. In this case we are recommended to soften the bead upon charcoal in the reducing flame, and then fuse it upon platinum wire in a pure oxidizing flame. If this makes it so dark as to be nearly opaque, the soft glass is pinched out, some of it broken off, and the remainder diluted with more borax. The cobalt is thus, as it were, washed out, while the oxidizing flame is employed to convert all the iron into the sesquioxide, which, of course, gives its characteristic yellow or brownish red color, according to the amount present. The volatile metals, as well as sulphur and arsenic, may be driven off by continued heating on charcoal in the reducing flame. Those not thus volatilized, such as copper, may be separated partly by reduction on charcoal and partly by the solvent action of borax or by lead. Various ingenious devices for these purposes are described. A few points worth recollecting by the student—and just those he is least likely to discover for himself—are those relating to the colors of borax or phosphorus-salt beads when containing a mixture of oxides. Iron peroxide, of course, gives a yellow or brownish bead, which may be overpowered or changed to green by cobalt; the blue of copper also makes it green while hot, and a little lighter green on cooling. This fact is utilized to determine whether iron is present as per- or protoxide, the assay being added to a borax bead containing oxide of copper. With sesquioxide of iron the bead becomes bluish green, with protoxide red spots of cuprous oxide become distinctly visible in it. Manganese in quantity completely obscures iron, producing in the outer flame a bead dark-red

while hot, and red, inclining to violet, on cooling. Reduction of the manganese to protoxide leaves the iron coloration alone; this in case of a small quantity of manganese can be effected on platinum wire, otherwise it is well to shake off the hot bead and heat it on charcoal in the reducing flame with tin.

Some of these separations, however, especially the quantitative ones, cannot wholly be effected in the dry way. An illustration of this is found in the treatment of a mixture of oxides of iron and chromium. In this case the color of the hot bead shows iron, but when cool only chromium. Though this gives the means of making a very good guess at these oxides, it is hardly sufficient to indicate the existence of iron with certainty. Hence, nitre and carbonate of soda must be used to convert chromium into alkaline chromate, which is dissolved out, the residue being fused up with borax again, when, if other coloring oxides are absent, the coloration of iron is obtained.

The quantitative assay of iron next described is really a combination of the blowpipe and the wet methods, intended for use only when the appliances for more accurate methods are not at hand. Very small quantities are employed, an assay centner—the weight usually taken—being equal to a hundred milligrammes. The method—which we need not describe in detail, referring our readers to the book itself—is essentially that of precipitating ferric oxide by ammonia, fusion with carbonate of soda being employed when necessary, and alumina being dissolved out by caustic potash. The constituents of an ore which occur in any quantity, such as silica, alumina, and lime, can also be determined by the simple methods described, while others, as manganese, baryta, sulphur, phosphorus and arsenic, may be detected, though their estimation can only be effected by regular analysis.

It is not to be expected that more than a small minority of assayers will ever be able to practise these methods with dexterity. But the mere attempts of a student to carry out these instructions of Plattner cannot fail to benefit him beyond a little. The best workmen frequently work with simple tools—witness Davy with his teacups—and very often even ordinary workmen are placed where only simple tools are available. So much can be done with the blow-pipe and its auxiliaries, which may all be carried in the coat pocket, that mineral explorers ought to make it a matter of duty to know how to use it, and we know of no book—after the A B C of blowpipe-work has been mastered—in which author, translators, and editor have done more to aid such students than the one before us.

## ON THE ELECTRO-MOTIVE FORCE OF FLUID BATTERIES.

From "The Telegraphic Journal."

This subject is studied by M. Paalzow in a recent number of "Poggendorf's Annalen." Kohlrausch alone appears to have previously endeavored to determine the electro-motive forces of liquids by the electrometric method ("Pog. Ann.," Bd. 79, p. 200). M. Paalzow repeated his experiments, but without success. The quantity sought is not only masked, but often exceeded by electricities, which the insulators of the measuring apparatus accumulate, and which, in the manipulations that are necessary, always recur.

With aid of the galvanometer, on the other hand, some good results have been obtained. Wild has shown that there are liquids which follow Volta's law of tension; Du Bois Re mond, that by insertion of distilled water into the series of members of liquid batteries, the highest value of electromotive force of liquids is attained. Worm-Muller considers that water is electromotively indifferent towards all liquids, from the fact that Kohlrausch has found no difference of tension between water and nitric acid, and that the thermal currents between water and other liquids are extremely weak. Two other facts appear to contradict this hypothesis: Faraday found that distilled water, in friction with other substances, gave the highest tension; and Quincke, that diaphragm-currents are considerable only with distilled water.

M. Paalzow's observations refer chiefly to the influence of the nature of the separating surface on electro-motive force, the constancy of this force, and the compensation for current work.

Previous experimenters have thought it indispensable to have a sharp surface of separation between the liquids. M. Paalzow at first fulfilled this condition. He specially studied a liquid battery consisting of amalgamated zinc in sulphate of zinc, hydrated sulphuric acid, distilled water, sulphate of zinc with amalgamated zinc. The liquids were in a series of large U-tubes, the first containing sulphate of zinc, the second sulphate of zinc and sulphuric acid, the third sulphuric acid and distilled water, the fourth water and sulphate of zinc, the fifth sulphate of zinc and the electrode of amalgamated zinc. The zinc electrodes were connected with a Wiedemann mirror-compass and the electro-motive force was measured by the method of compensation.

The sharp separating surface was obtained (between sulphate of zinc and sulphuric acid, *e. g.*) thus:—The sulphate was first poured into the U-tube, then the other liquid poured through a funnel with its very fine orifice at the surface of the sulphate of zinc, and a good deal of blotting-paper in the wider part. Adjoining tubes were bridged over by a syphon tube, the ends of which were bent upwards in the liquid.

Having compensated such a battery, M. Paalzow disturbed the several separating surfaces with a glass rod, and he found that the electro-motive force continued the same, the needle of the compass remaining at zero. Thus, in liquid batteries, a sharp surface of separation is not of consequence, if care be taken that one liquid do not penetrate through the second to the third. This was prevented in the present case, the liquids in the syphon tubes remaining unaltered.

While the result was surprising, it might as the author remarks, have been expected; for only in solids is a sharp surface of separation possible.

The battery described continues a pretty long time constant, owing to the great resistance and the consequently small current-work. After some time the electro-motive force decreases, owing to chemical processes. The positive current has, in the battery, the direction from sulphate of zinc to acid, to water, and to sulphate of zinc. Thus, through electro-chemical processes, there is at the zinc pole of vessel I a dissolving of the zinc; at the surface of separation between sulphate of zinc and sulphuric acid, formation of sulphuric acid; at that between sulphuric acid and water, formation of water, at that between water and sulphate of zinc, formation of sulphuric acid; and at the last zinc pole separation of zinc. Thus, after some time, sulphuric acid is inserted between the water and the sulphate of zinc, and owing to the symmetrical arrangement now approaching in the liquids constituting the battery, the electro-motive force must gradually be reduced to zero. Considering, in the case of liquid batteries, the chemical process in the battery itself, it readily appears that only those batteries can furnish a constant electro-motive force, in which all the constituent liquids contain either the same acid or the same radical.

According to the principle of conservation of force, we expect a compensation in the battery itself for the current afforded. In the battery under consideration, sulphate of zinc, hydrated sulphuric acid, water, sulphate of zinc, one would seek this compensation in the caloric processes between the constituent liquids. From these the chemical processes, in reference to their calorific values, are, as previously shown, eliminated; there remain for compensation, only the processes of diffusion. To ascribe it to these. M. Paalzow thinks impossible, for he has found a battery in which, through processes of diffusion, only cold is produced, and which yet furnishes a strong current. This is the combination: Sulphate of zinc, muriatic acid, acetate of protoxide of zinc, sulphate of zinc, between zinc electrodes. Of the diffusion process here, muriatic acid mixed with sulphate of zinc gives a lowering of temperature; also muriatic acid with acetate of protoxide of zinc; acetate and sulphate of protoxide of zinc mixed, give no change of temperature.

"I distinguish, however, in the hydro-batteries generally, those chemical and diffusion processes, which also occur with the open circuit, from those which are called into play through closure of the circuit. It is only to the calorific values of the latter that the compensation for current work can be attributed. This may be explained with a Daniell element. If in constructing such we use amalgamated zinc, which, before closing of the circuit is hardly attacked at all, then, after closing, the entire calorific value of the chemical process in the battery is equivalent to the current-work.

If, however, unamalgamated zinc be taken, there are two chemical phenomena to be distinguished—the dissolving of the zinc which would occur even in the open circuit, and that which is produced by the current. I have convinced myself by experiment that the purely chemical dissolving of the zinc in the closed circuit is equal to that which would occur in the open circuit, and that the current work corresponds only to the quantity of zinc which is dissolved by the current.

"A Daniell element was constructed, the zinc was not amalgamated, the circuit was open. The sulphuric acid had a sp. gr. 1.043. The zinc plate weighed before the experiment, 21.859 gr. After remaining twenty minutes in the open circuit, it weighed 21.114 gr., having lost 0.745 gr.

"A second Daniell element was made as like the first as possible. The circuit was closed, and the voltameter inserted (with copper electrodes in sulphate of copper). The unamalgamated zinc plate weighed before the experiment, 21.893 gr.; and after the experiment, which lasted twenty minutes, 20.927 gr., having thus lost 0.966 gr. In the copper voltameter 0.244 gr. copper was separated out. The quantity of zinc equivalent to this, whose separation was attributable to the current, was 0.250 gr. In the closed circuit there was thus dissolved by the purely chemical process, which also occurred in the open circuit 0.966 gr.—0.250 gr.=0.716 gr. The quantity of zinc is almost the same as the first zinc plate lost in the open circuit.

"With the same kind of zinc and sulphuric acid of the same specific gravity, several experiments were made, the results fully agreeing with those described. This appears to me important in reference to the contest between the chemical and the contact theories (though I cannot here pursue the subject further).

"If, now, we were to ascribe the current-work of liquid batteries to the caloric values of the diffusion processes, it must only be those which appear in the closed circuit; and evidence must be furnished that the diffusion takes place differently in the closed circuit from that in the open. Hitherto, such proof is wanting. But according to the experiments with the battery, sulphate of zinc, muriatic acid, acetate of protoxide of zinc, sulphate of zinc, the current here can neither be attributed to the one nor to the other, inasmuch as cold is produced by the diffusion.

"I incline, therefore, at least in the case of liquid batteries, to Nobili's opinion, that the currents produced by them have similar origin to that of thermal currents, and that the compensation for the current-work is to be sought in the heat absorbed from without. I am at present occupied in experimentally testing this view."

## ON RECENT DISCOVERIES IN MECHANICAL CONVERSION OF MOTION.

From "The English Mechanic."

The following is an abstract of the official report of the lecture delivered by Prof. Sylvester, F.R.S., at the Royal Institution, the chief discovery of which it treats being that known as Peaucellier's parallel motion. The report is accompanied by voluminous and instructive notes, for which however we have not space. The speaker stated that the subject he proposed to bring under the notice of the meeting related mainly to the discovery of a perfect parallel motion, that is to say, of a mode of producing motion in a straight line by a system of pure link-work without the aid of grooves or wheel-work, or any other means of constraint than that due to fixed centres, and joints for attaching or connecting rigid bars. This important discovery was made by M. (now Colonel) Peaucellier, an officer of Engineers in the French Army, and first published by him, in the form of a question in the "Anneles de Mathamatique" in the year 1864. Before Peaucellier's time all so-called parallel motions were imperfect, and gave merely approximate rectilinear motion; in substance they will be without exception found to be merely modifications of Watt's original construction, and to depend on the motion of a point in, or rigidly connected with a bar joining the extremities of two other bars rotating round fixed centres, which may be described briefly as three-bar motion. Peaucellier's exact parallel motion depends on a link-work of

seven bars moving like Watt's, and the other imperfect parallel motions of the same class round two fixed centres.

To understand the principle of Peaucellier's link-work, it is convenient to consider previously certain properties of a linkage, (to coin a new and useful word of general application), consisting of an arrangement of six links, obtained in the following manner:—first conceive a rhomb or diamond formed by four equal links joined to one another; and now suppose a pair of equal links to be joined on to two opposite angles of such figure and to each other. All six links are supposed to lie (and to be constrained by the nature of their attachments to remain) in the same plane. The point of junction of the last-named pair of links (which it will be found convenient to call the fulcrum) according as they are greater or smaller than the sides of the diamond, will lie outside or inside the diamond. The linkage consisting of the six links may be termed a positive *cell* in the one case and a negative *cell* in the other.* It is easily seen, as a geometrical necessity, that the fulcrum, in whatever way the linkage is moved about, will always lie in a straight line with the two free angles of the diamond, which may be called its poles, and the distances of these poles from the fulcrum, or the ideal lines which represent those distances, may be called the arms of the cell. It is upon the geometrical relation between these arms that the remarkable mechanical properties of Peaucellier's cell depend. The cell may be made to change its form like a set of lazy-tongs or any other kind of linkage, by closing or opening the diamond; as this is done evidently the lengths of the arms alter; but it will be found, and is capable of easy geometrical proof, that they remain subject to a very simple condition, viz., one increases just as much as the other decreases, so that their product remains invariable; this product is equal to the difference between the square of either of the links (called the connectors) proceeding to the fulcrum and the square of any side of the diamond, to which we may give the name of the modulus of the cell. The speaker illustrated this property experimentally, using a negative cell for the purpose. When the fulcrum was midway between the two poles each arm was 12in. in length. When one arm was made 18in. the other was found to be 8; when again it was stretched to the length of 24in. the other was 6, and so on, the product of the two remaining always 144; or, reckoning in feet, to the lengths 1, 3-2nd 2, 3 of one arm corresponded the lengths 1, $\frac{2}{3}$, $\frac{1}{2}$, $\frac{1}{3}$ of the other; showing that the length of one arm was so governed by the length of the other as that the numbers denoting the two were always inverse or reciprocal to each other when the modulus is taken as unity. Hence a Peaucellier's cell may be conveniently termed a Reciprocator or Inverter. If we were to suppose the connectors at their free ends, instead of being attached to the side angles of the diamond, to be joined on to two adjoining sides in such a manner as to become parallel to the other pair of sides, this parallelism would continue to subsist for all positions of the linkage, and the arms or distances of the fulcrum from the opposite angles or poles of the diamond would still remain in the same right line, but the relation between them would now be one of direct instead of inverse proportion. Conceive the fulcrum in such an arrangement to become fixed. Since we cannot only alter the angles of the diamond, but make the whole arrangement turn round the fixed point, we can make either pole describe any plane curve whatever; the other pole will then describe a curve precisely similar in shape, but drawn on a different scale, as in any ordinary pantigraph.

But if we revert to the Peaucellier cell or Reciprocator, whether of the positive or negative form, and treat it in the same manner as the supposed pantigraphic arrangement, fixing the fulcrum, and making one of the poles—*i. e.* an extremity of one of the arms—describe any plane curve, the other pole will no longer describe a similar curve, but what in the language of geometry is termed an inverse of the curve in question, the fulcrum being the origin of the inversion.

* Mr. Penrose, the architect, and surveyor to St. Paul's Cathedral, has put up a house-pump worked by a negative Peaucellier cell, to the wonderment of the plumber employed, who could hardly believe his senses when he saw the sling attached to the piston-rod moving in a true vertical line, instead of wobbling as usual from side to side. There seems to be no reason why the perfect parallel motion should not be employed with equal advantage in the construction of ordinary water-closets. The author has been admitted to see the geometrical pump at work in Mr. Penrose's kitchen at Wimbledon. A sister pump of the ordinary construction stands beside it. The former, although quite as compact as its neighbor, throws up a considerably larger head of water with the same sweep of the handle. Its elegance, and the frictionless ease with which it can be worked (beauty as usual the stamp and seal of perfection) have made it the pet of the household.

Suppose now one of the poles is made to describe a circle, the other will describe the inverse of a circle, which geometricians are well aware will in general be another circle, subject to the exception that if the arc described by one pole is part of a circle passing through the fulcrum which is here the origin of the inversion, the path of the second pole will be no longer a circle, but a perfect straight line, which, under a mathematical point of view, may be regarded as a circle with an infinite radius. If, then, in addition to fixing the fulcrum, we still further constrain the motion of the Peaucellier cell by attaching one of the poles to a centre (which for the sake of distinction from the other fixed point above defined we may term the *pivot*) round which it can revolve, situated at an equal distance from that pole and the fulcrum, the other pole will describe a perfect straight line perpendicular to the line joining the fulcrum and the pivot. We have thus a combination of seven radiating bars attached to two fixed centres, one point of which describes a true rectilinear path, and thus the long-sought-for problem of a perfect parallel motion meets for the first time its complete solution.

The speaker illustrated these results by various models constructed in wood. By changing the length of the radial bar connecting one pole of the cell with a fixed point, the free pole was shown to describe arcs of circles convex or concave to the fulcrum, according as the ideal circle, in an arc of which the first-named pole moved, fell short of the fulcrum or contained that point within it; in the limiting case, when it passed through the fulcrum, the path was shown to be neither convex nor concave, but a straight line free from all curvature in either direction. This was further verified mechanically by connecting together at their free poles two perfectly equal and similar mounted cells. If the tendency of either of these was to deviate from the straight path, the tendency of the other would be to deviate in the contrary direction; so that either the pair of mounted cells would become an absolute fixture, or the two would crush or tear each other to pieces; but in the experiment exhibited, the pair of mounted cells were seen to move together (as if in happy wedlock), without let or hindrance to each other's motion. The circular motion of the free pole of a single mounted cell in the general case was also verified experimentally, and even more simply than in the rectilinear case, by the addition of a second radial bar, taken of a suitable length, determined by previous mathematical calculation. As a general rule, the total number of bars in a link-work machine must be odd, but here there were eight bars, and yet the combination admitted of being set in free motion—any one of the eight being, in fact, what may be termed a lazy-bar, and capable of being removed without disturbing the motion, very much in the same way as any one of the four legs of a table may be removed without disturbing the equilibrium.

The speaker pointed out the important applications of the two kinds of motion above referred to (which he proposed to call the circulo-linear and the circulo-circular respectively) to various constructions in machinery, such as the steam-engine, planing and grinding machines, the construction of maps on the stereographic projection, millwright's work, laying out of railway curves, dioptric apparatus for light-houses, ornamental tracery, pendulum suspension to effect motion in a practically exact cycloidal arc, &c., &c., and referred to the use which, as he was informed by the authorities at Woolwich, might have been made of the circulo-circular adjustment in saving several week's work, inconvenience, and expense in cutting out the fish-bellied torpedo casings recently constructed in the laboratory department at the Royal Arsenal there, and the use contemplated to be made of the circulo-linear, or perfect parallel motion, for guiding a piston-rod in certain machinery connected with some new apparatus for the ventilation and filtration of the air of the Houses of Parliament, now under course of construction.

He next referred to the unlimited command over the motion of a point furnished by a combination of cells. Returning to the simple Peaucellier cell, its use may be modified in a very remarkable manner by setting free the point of junction of the two connectors (termed, in what precedes, the fulcrum), and fixing one of the poles as a centre of rotation in its place. If now the liberated fulcrum be made to describe any curve, the free pole will describe a curve corresponding to it, according to a certain easily-statable mathematical law. Imagine the first-named curve to be part of a circle passing through the fixed point—it may be shown that in that case the free pole will describe the inverse of a conic section in re-

spect to a vortex of the conic as the origin of the inversion; consequently, by combining with this cell a second, used as a Reciprocator, we may, mounting with a suitable radius a pair of Peaucellier cells duly adjusted, cause a point to move in a parabola, ellipse, or hyperbola.

The speaker exhibited a combination of this kind, and caused a point to describe portions of an ellipse, a parabola, and of the two branches of a hyperbola in succession; the traversing pole of the first cell, which might be termed the first follower, being seen to descr.be beautiful nodal cubics (or the inverses of the conics), while the free pole of the second cell or second follower described the conics themselves.

He next went on to state that by a combination of cells properly proportioned and suitably attached to each other in succession in a manner similar or analogous to that in which simple machines, as for example, a number of levers, may be combined to produce a complex one, we are able to bring about any mathematical relation that may be desired between the distances of two of the poles of a linkage from a third, and are thus potentially in possession of a universal calculating machine. He exhibited and worked a cube-root extracting machine constructed on this principle, and claimed to have given the first really practical solution of the famous problem proposed by the ancients of the duplication or multiplication of the tube. This machine consisted of a combination of three cells; by changing the modulus of one of the three, he explained that it was also quite easy to solve the cubic equation involved in the analytical solution of the problem of the tri-section of the angle; and a working model of an instrument of this kind executed in zinc was exhibited by Professor Henrici after the lecture. He concluded by expressing his great obligations to this gentleman, without whose aid he would have been able to do little more than adumbrate in general terms the results which, thanks to his friend's practical knowledge and skill, he had had the pleasure of exhibiting in a tangible form, and submitting before his audience to the test of actual experiment.

## BLAIR'S IRON SPONGE MANUFACTURE.

From "Engineering."

The manufacture of wrought iron and steel directly from the ore, has always presented great attractions to experts and ironmasters, because it dispenses with the roundabout method of the blast furnace; because it avoids the blast furnace combination of other metals and impurities with the iron, which metals and impurities, chiefly carbon, silicon, and in some cases phosphorus, have to be subsequently removed by additional and costly processes, in order to produce good wrought iron and steel; and because iron ore can be deprived of its oxygen, and thus made into sponge, without a melting temperature, and hence without rapid destruction of the furnace, and without blowing engines and other such costly machinery.

It is unnecessary to tell the student of iron metallurgy that the attractions of the direct process have won a host of admirers, whom it has led, like an *ignis fatuus*, through the quagmires of metallurgical chemistry and engineering, into the dismal swamp of bankruptcy. The crumbling remains of reducing furnaces in every country, are even stronger evidences of abortive effort in this direction, than are the historical literature of the iron manufacture and the assurances of certain distinguished experts that the thing cannot be done to commercial advantage.

But the failure of previous efforts does not disprove the correctness of the theory upon which these attempts have been founded, any more than the failures of Kelley and Shunk and Martien, and the oft and apparently hopeless early failures of Bessemer, disprove the correctness of Bessemer's theories, or limit the vast field of his operations.

It should appear from the history of iron metallurgy, and especially from the history of the Bessemer process, that every scheme that is well founded in chemistry, however refractory and hopeless may be its mechanical conditions, will ultimately be put upon a working basis; that ingenuity, coupled with persevering experimenting, will at last discover the missing link.

This appears to have been the case with the direct process. Mr. Thomas S. Blair,

of Pittsburg, U. S., an ironmaster of some 25 years' experience, a good chemist, and a gentleman of ample means and resources, having these advantages, and being perfectly familiar with the difficulties to be encountered, undertook this problem with the determination of solving it, however long it might require, and without the necessity or anxiety of ordinary inventors, to realize on an undeveloped idea. Some four years, not of random trials, but of consecutive steps, constantly guided by chemical determinations, and on a scale which made commercial probabilities constantly measurable, have brought the manufacture and utilization of sponge to the degree of chemical, mechanical, and commercial success to which it has now attained in America.

It is only necessary to mention here the grand difficulties which have heretofore rendered all efforts in this direction either abortive, or extremely limited in their application; the literature of the profession abounds with the details. The first difficulty was in securing the uniform reduction of a large amount of ore. A tube a few inches in diameter, filled with iron ore and the necessary carbon, averaging 30 per cent., and subjected to a red heat for a few hours, is a perfectly practical reducing furnace, chemically, but not a perfectly practicable one commercially. When furnaces were made large enough to fulfil the latter condition, it was found, even in the furnace of Chenot, the best before Blair's, that the central core of ore in the cylinder was not perfectly reduced. And it has further been ascertained that this want of uniformity in the product, especially the destructive action of the unreduced ore on the walls of the furnaces in which it was further manufactured, have rendered its use impracticable. The second grand difficulty has heretofore been the reoxidation of a part of the sponge, either while cooling, or while in or while being transferred in a hot state to the puddling or balling or melting furnace for further manufacture. As before stated, the professional literature on this subject will supply the details of previous failures from these causes.

It is not to be denied that Mr. Blair has had the advantage of the early experimenters in having the gas furnace and its high heats with comparatively neutral flames at his command for the purposes of further manufacture; but it is equally not to be denied that Mr. Blair has overcome previous difficulties inherent in the sponge itself; for the long continued sponge manufacture of Chenot (which was however at last abandoned for the reasons mentioned), and the best other sponge manufactures preceding Blair (all of which are now abandoned from the same causes), were known and practised long after the Siemens furnace was in use, and even after the Siemens-Martin process was in successful operation; but the previous sponges were never successfully used, even with the aid of the gas furnace.

The two grand features of Mr. Blair's system of reduction, which meets these two great defects of previous systems, will appear from an examination of the illustrations we publish on page 132, which show one of six nests of furnaces, now running at the Blair Iron and Steel Works, at Glenwood, near Pittsburg. The three firebrick reducing cylinders K are 4½ ft. in internal diameter, and stand 42 ft. high from the ground to the charging platform. They are surrounded (and supported as shown in Fig. 1) by a strong red brick stack R, lined with firebrick, and standing on the columns and establature M. Gas from ordinary producers is distributed by the pipes C D and the burners E to the annular spaces around the cylinders, where it meets jets of air and burns, encircling the cylinders with a uniform flame and keeping them at the necessary red heat. The products of this combustion pass off by the chimney Q. A cast-iron thimble J is placed as shown, in the top of the cylinder, a 5-inch annular space being left between the outside of the thimble and the inside of the cylinder. Into this annular space the ore, mixed with the necessary coal for its reduction, is charged. This thin annular charge is heated from without by the producer gases, as before mentioned. It is also heated from within by the combustion of producer gas admitted to H by the pipe F and air introduced by the pipe G. The carbonic oxide arising from the deoxidation of the ore below, also burns within the thimble. The heat thus communicated to the charge has only to penetrate it 2½ inches from either side, the result of which is, and obviously must be, the rapid and uniform heating of the ore and the carbon mixed with it. This having been done, the difficulties, as far as reduction is concerned, are over. Nothing more is neces-

sary but to keep the charge up to the temperature which it has acquired in the annulus, and to give it time for the chemical reaction to take place. It has been ascertained that with the proportions, shown in in the engraving, the charge acquires the necessary heat by the time it reaches the bottom of the thimble, and that it is perfectly reduced by the time it has descended to the bottom of the external heating chamber (L, Fig. 3), when it is passed through at the rate of 20 tons (of iron in the sponge) per week per cylinder, or 60 tons per week per three-cylinder furnace. Thus the first difficulty of previous reducing operations is overcome; the charge having been uniformly heated, and so surrounded by flame that it cannot get cool till reduction is completed, uniformity of reduction is absolutely secured.

Now, however, a new condition has arisen. The deoxidized sponge at a red heat is so sensitive to oxygen that it will take up air from the smallest exposure, and so be irregularly turned back into ore again. For this reason every attempt to remove the sponge in a red-hot state to a heating or melting furnace has been attended with great loss and irregularity of product. It is, of course, impracticable to seal the hot sponge perfectly against the entrance of air, either by air-tight discharge valves, or by a slight excess of pressure in the cylinder, for by the law of transfusion of gases, the heavy will rise into the light, and the light will descend into the heavy gases, unless there is a decided current to be overcome. Mr. Blair meets the difficulty by simply prolonging the cylinder below the zone of reduction, far enough to allow the charge itself to form a packing against the entrance of air. The lower part of this prolonged cylinder is cooled by the water jacket N N, and is made so long that the charge will in its regular descent from L to the floor, where it is removed, get cool enough to be held in the hand. At this temperature it will not oxidize for weeks. So that any air which may leak in from below comes in contact with cold sponge which it cannot hurt; and this column of sponge, compressed together by the superincumbent weight of all the charges above, prevents any air from penetrating where the sponge is hot enough to be injured by it. The sponge is withdrawn by lifting the sleeve P at the bottom of the cylinder. The cone O promotes the uniform discharge of the interior and exterior parts of the column of sponge. When the requisite quantity is drawn, the sleeve is driven tightly down to the floor, and luted with clay.

The working of the furnace is probably simpler and less likely to go wrong than any other metallurgical operation where heat is employed. It is only necessary to see that the charge, as it escapes from under the thimble into the body of the cylinder S, is sufficiently hot, and to draw the cold sponge a little more slowly if it is not; also to keep a uniform temperature in the external heating chamber by observing the flame through sight holes in the top of this chamber, and regulating the air and gas admission accordingly. It has been found much more convenient at Glenwood to use in this heating chamber gas which is originally free from tar, like that from coke or anthracite, or gas from which the tar has been removed by washing. By employing small coke—the *débris* of coke yards—with a slight blast in the producers, a clean gas is made, which will not clog the small burners. The character of the sponge—its state of proper deoxidation—is very easily and certainly determined by its lustre, color, and feeling, and especially by its appearance and softness when cut with a knife.

The carbon charged in with the coal may be either coke, anthracite, or charcoal. It should be crushed, so that its coarsest pieces will pass an inch mesh screen, and the ore should pass a 1½ inch screen.

There is apparently no limit, perhaps within blast furnace dimensions, to the size of the reducing cylinder. The first one that made sponge on a commercial scale was 11 in. by 13 ft. Two successively larger sizes were then employed with constantly improved results; and the present furnace (4½ ft. by 42 ft.) is easier to manage and much cheaper per ton of product than the smaller ones.

The cost of sponge, as determined from over three years' commercial practice, averages about £1 less per ton of iron in the sponge, than pig iron made from the same ores. All ores of moderate richness (not necessarily very rich ores) that are pure enough to make the commoner sorts of Bessemer pig, are certain to make a most excellent sponge. Mr. Blair has made a number of satisfactory experiments with lean ores, and also with ores containing that

class of impurities which will leave the sponge just as silica will when the sponge is fused in a Siemens-Martin bath; for instance, ores containing phosphorus combined with lime; but as these are not yet matters of every-day practice we will not follow them further at present.

The best method of utilizing sponge, in the present state of the art, is to substitute it for wrought-iron in the Siemens-Martin, or open hearth process. No new apparatus or treatment of any sort are required in this part of the operation. The cold sponge is simply thrown into the pig-iron bath; it instantly disappears under the slag; it is, from its porosity, rapidly melted; its silica and all its earthy impurities rise to the surface, and the iron remains. The amount of slag is somewhat larger than where wrought-iron is used, but if a lean ore is employed the excess of slag is tapped off. The first time this sponge was ever used in an open hearth furnace, it was charged in the proportion of three quarters sponge to one quarter Bessemer pig, with the usual spiegel; and the product was excellent boiler plate, and was sold as such. The waste was almost exactly the same as with charcoal blooms

In the early practice it was thought necessary to compress the sponge, cold, into blooms of about one-third the density of iron; but this process is now only employed with the very fine sponge; the coarse gives equally good results when charged in its loose state.

The advantages of sponge in the Siemens-Martin steel manufacture is obviously these: First, the material is better than that obtained from the same ore by any indirect method. No ore is reduced except the ore of iron. For instance, the silica is not reduced to silicon, but is simply baked sand, which subsequently floats off in the bath; and thus one principal bane of fine steel is dispensed with. The same is true of most of the other impurities It is not true, however, of sulphur and of phosphorus when combined with the iron in the ore.

Second, the sponge is cheaper than any material that can be obtained from the ore by any indirect method. The use of raw ore in the Seimens-Martin process is by no means an equivalent. Only enough raw ore can be used to make up the loss—to restore the iron oxidized in the process. The other material put into the bath is less pure than sponge, and costs, on the average, more than pig-iron, while sponge costs less.

Mr. Blair has made some very encouraging trials in welding sponge, also in carburizing it, so as to use it in the open-hearth furnace without admixture of pig-iron; but as these are details not yet fully worked out, we will pospone their consideration.

## TECHNICAL EDUCATION.

Written for Van Nostrand's Eclectic Magazine.

While technical and scientific schools are multiplying themselves all over the country, and sending forth every year a graduated class of young men, aspirants for positions as civil engineers, it may not be inappropriate to inquire how far the instruction afforded by such institutions is calculated to benefit and advance its recipients, and, more particularly, how far it is indispensable to success in the career of civil engineer.

In other professions, the evidence is clearer. It is so well known as a practical fact, that no man can possibly be a doctor or a lawyer without devoting many years to hard book-work, that taking a degree, *i. e.*, obtaining a certificate that this work has been satisfactorily performed, is necessary to enable one to practice either as doctor or lawyer.

In engineering the case is different. In the face of the many admirable works which we see every day planned and executed by "practical men," *i. e.*, men who owe but little to any school save that of observation and precedent, it would be hard to say what, if any, special education was indispensable to an engineer. Moreover, we venture the assertion, which we feel confident no engineer will undertake to challenge, that in one very important branch of the profession, that of railroad engineering, success depends upon conditions wholly disconnected from books and schools. In other words, a man after passing through a four years' course of laborious study, may

enter a railroad corps, spend his life in railroad engineering, rise to the chief engineership of the most important line in the country, and during all that time never have occasion to recall one single item of the instruction of his four years' course.

Undoubtedly, in running the transit (and at this exhilarating exercise he will probably pass an apprenticeship of several years) he must know enough of the plainest of plane trigonometry to be able to work around an obstructive schoolhouse and get back to his line again, and to find his way to any ground indicated by the assistant engineer; but all this, and the like, only requires that amount of mathematical knowledge usually taught in seminaries for young ladies, and if he has not already acquired it he can readily pick it up as he goes along.

If, on the other hand, our student gets into construction, he will find throughout that scientific knowledge waits upon practical experience; and if he is wise, for one scientific counsel that he takes from his text books, he will take twenty practical ones from the foreman of the works. After calculating the dimensions of his battering retaining wall, he had a great deal better submit his design to the boss mason than to the faculty of his engineering school.

The great difficulty in reducing engineering to a written science, so as to admit of its being learned from books, is the determination of data. The elements which force themselves in practice into the problem are so manifold and perplexing as to baffle the attempt to catalogue them; but their existence is *felt* by the practical man, and a faculty which is to obscure questions of construction what conscience is to moral ones, whispers to him the proper course to pursue, where engineering ethics would altogether fail him.

Not only is it difficult to specify all the data entering into engineering problems, but it is still more difficult to recognize them when encountered in practice. For instance, in the matter of foundations, the student may be taught that a certain system of founding is applicable to cases where the natural soil is capable of sustaining the weight of the intended superstructure, while a different plan is to be followed when it is not. Fancy the hopeless condition of the young gentleman *ætat.* 21, graduated A1 from a crack technological school, brought face to face with the "natural soil," and obliged to decide, from the light shed on the subject by his books, what kind of foundation he should put in! Of course it is true of all professions that a certain amount of practical experience is necessary to enable one to wield his theoretical knowledge, but it is so largely true of engineering that it would seem in some cases that the theoretical part was completely thrown out of the record, and as if any attempt to recall rules and figures would simply impede the only true guides; *i. e.*, practical judgment and artistic intuition.

What, then, are the advantages of a technical education to the engineer? In spite of what we have written above, we take them to be very great indeed, far greater, in fact, than can appear from any short-sighted utilitarian view of them. All that we have said involves no paradox, but simply proves that, as yet, engineering is an art rather than a science, and as such gains more from individual qualities, supplemented by individual experience, than from the application of established rules that may be taught and learned, and which are as effective in the hands of a comparative dunce as in those of a man of transcendent genius. Of the laws governing the forces with which in engineering we have to deal, we can claim but an imperfect knowledge. Still, these laws do exist, and every successful effort to recognize them and reduce their action to an equation, raises the art of engineering, by so much, from a mere trade, governed by empirical maxims, toward the dignity of a liberal profession.

In the effort to make engineering an exact science, practical difficulties, *i. e.*, elements neglected in the theoretical calculation, but none the less potential in practice, will of course encumber our path; but these elements are being constantly detected and noted, and added to the specification, making our data constantly more and more complete. Everything connected with engineering construction is susceptible of mathematical calculation—and usually a very simple calculation—when we are sure that we have all the elements coming into play, and one of the objects of a technical education is to give the student such command of the resources of mathematical investigation as to enable him to figure out, with confidence in his results, any new problem presented to him.

The great mistake committed by the graduates of our technical schools is in

supposing that because they have in their pocket the degree of civil engineer, that they are therefore, actually and truly, engineers. No mistake could be more fatal. A freshly graduated medical student might as well think he was a doctor; and with greater reason, in fact, for he at least has seen a good deal of *genuine work* in the hospitals, done by the most eminent members of his profession. It is quite natural, certainly, that a young man who has sedulously devoted himself to years of patient, special study, should consider that at the end of that time he was qualified to practice what he had been so long learning; but he should recollect that all this was preparatory work, and that on leaving his school he was just ready to begin learning his profession. Whenever this fact is realized, and the student commences earnestly to work at his profession after graduating, he will find his preparatory education of inestimable advantage to him; whenever it is ignored, and the student imagines that his studies have placed him beyond the need of further work, and above all merely practical men, he will find that instead of an aid, they are the worst clog he could have placed upon his future. He may be a pedant, but never an engineer.

## USE OF TIMBER IN CONNECTION WITH MECHANICAL WORK.

From "Iron."

At the meeting of the Manchester Scientific and Mechanical Society, briefly noticed last week, Mr. J. G. Tynde, C. E., borough surveyor, Manchester, during the course of his presidential address, dwelt at some length on the use of timber in connection with mechanical work, both with regard to pattern-making and in relation to the erection and removal of heavy machinery.

The proper selection and use of timber, he said, was a matter in which they were all more or less interested, and he would offer a few observations on the subject, based on his own experience. For all ordinary purposes the kind of timber most used for pattern-making, and in temporary structures, such as travelling cranes, staging framework, and platforms for the erection of bridges and similar work, was fir, either American or Baltic, the nature and properties of the different descriptions of which, as usually met with in our market, he proposed shortly to describe; but before doing so it might be interesting if he gave a very slight sketch of its introduction to this country. Previously to the colonization of America our supply of fir timber was obtained from the countries on the coasts of the Baltic, of which Norway, Russia and Sweden were the first resorted to. The colonization of America, however, soon opened a large and valuable field for obtaining timber of similar growth, the two Canadas especially yielding large supplies of a very fine quality. More recently a supply of the same kind of timber had been obtained from Savannah and the adjacent States of America, and efforts were now being made to open a trade with California, where was to be found some of the finest red wood ever brought into our market. Fir timber might be divided into three distinct classes, known by the color of their wood—by white, yellow and red. American spruce deals belonged to the first-named class, and were principally used for joists and bearing timbers in common houses as well as for scaffolding in the erection of machinery. There was so much of a very inferior quality of this kind of timber that it was necessary a very practical knowledge of it should be acquired by those under whose directions it was used, as serious accidents frequently happened when it was misapplied. Baltic white deals were wood of a very fine texture, and used principally for the same purposes as the American spruce deals. This timber would not, as a rule, bear so great a load as the American, but it was much less liable to warp from change of temperature. Both these kinds of timber were specially liable to decay if placed in warm and moist situations, fungi speedily forming on them, and causing what was commonly known as dry-rot; and when once this had been commenced, the wood was no longer to be depended upon. These woods were both extensively used for packing-cases for machinery, and for this purpose were quite as good as more expensive timber. The next class of timber to which he would direct their attention was the American yellow pine. This timber was

imported in logs, and cut up into boards or scantlings in this country; like the white wood, this timber was practically non-resinous; it was of a fair texture, and when not exposed to damp was durable. It was much used for building purposes, especially for joiners' work that was covered with paint. As a bearing timber it had a peculiar quality—viz., that it retained its form with a permanent load; whereas many kinds of timber when loaded continued to deflect for years, although the load might not be greater than they might safely be required to bear. Unless, however, this wood was properly treated from the log, its valuable quality of retaining its form was materially impaired. The log should be opened and cut into boards in the autumn, and exposed to the weather through the winter; in the spring it should be removed into the drying shed, and thence into a room having a corresponding temperature with that wherein it was to be stored when finished, for at least one month before being worked. On no account should this wood be placed in a stove, as in its removal from a high temperature it would always be liable to change its form. There were many qualities of yellow pine, and their quality varied very considerably. Next, referring to the red wood, he said this timber was imported both from America and the Baltic in the form of both logs and deals. There were several varieties of red deals, each possessing its own peculiar character; but all of them more or less valuable on account of their power to resist atmospheric changes and the action of moisture. It was, therefore, much used in engineering works for piles and timber framing exposed to the weather, railway sleepers, and all places where it was necessarily shut out from a free passage of air. It was also less liable than any other kind to dry-rot. The timber imported from Sweden was generally of a very inferior quality and of small size; it was very liable to crack if exposed to the sun, causing what were known as "sun-strokes." The custom at all the ports on the arrival of the timber was to put the logs into water to prevent this. The pitch-pine imported from the Southern States of North America, Savannah, and Pensacola, was of a strongly resinous character, but had a great tendency to dry-rot, especially if it was placed in contact with fresh mortar and lime. This timber was, therefore, unfit to be built into walls as bearing beams, unless the ends were placed in cast-iron boxes, or were otherwise protected so as to allow a free circulation of air round the ends of the beams. Many samples of this timber had a beautifully waved grain, and would take a high polish, and these were selected and used for ornamental joiners' work. One peculiarity in connection with all red-wood was, the varied qualities found in the same log; the lower part of a tree might be exceedingly good, while the upper part might be very inferior. From the remarks he had made, it would be seen how impossible it was to fix any arbitrary formula that would be applicable for calculating its strength, the quality being so variable the same formula would not apply in any two cases. He had tried some experiments on a sufficiently large scale to guide his own judgment, and he found that for a very good and selected sample of Baltic timber the following simple formula for beams might be relied upon:—the breaking weight in the centre equalled the product of the breadth with the square of the depth multiplied by .15, and divided by the length in feet; and for an ordinary sample of timber he usually took the safe load in the centre in tons equal to the product of the breadth, with the square of the depth multiplied by .03, and divided by the length in feet.

The President then brought his remarks to a close, with the expression of the hope that the subject would be again referred to, and other descriptions of timber dealt with.

## PRODUCTION OF PIG IRON IN THE UNITED STATES IN 1872 AND 1873.

From "The Bulletin."

We present herewith full and accurate statistics of the production of pig iron in the United States in 1872 and 1873, derived from returns made directly to the office of the American Iron and Steel Association by the makers and by the regular correspondents of the Association. This exhibit is the most complete of the kind

that has ever been given to the country, and its preparation alone has cost the Association thousands of dollars. We briefly summarize the leading facts set forth in the detailed statements which follow, premising them by remarking that our tables do not include abandoned furnaces:

| | |
|---|---|
| Whole No. of stacks December 31, 1871..... | 571 |
| Whole No. of stacks built in 1872..... | 41 |
| Whole No. of stacks December 31, 1872..... | 612 |
| Whole No. of stacks built in 1873..... | 50 |
| Whole No. of stacks December 31, 1873..... | 662 |
| Whole No. of stacks in blast Jan. 1, 1874.... | 410 |
| Whole No. of stacks out of blast Jan. 1, 1874. | 252 |
| Whole No. of stacks completed in first 6 months of 1874..... | 11 |
| Whole No. of finished stacks, July 1, 1874... | 673 |
| Whole No. of stacks building July 1, 1874... | 53 |
| Whole No. of stacks projected, July 1, 1874.. | 61 |
| Total production in 1872, tons of 2,000 lbs.. | 2,854,558 |
| Total production in 1873, tons of 2,000 lbs. | 2,868,278 |
| Estimated annual capacity of all finished stacks, net tons..... | 4,500,000 |
| No. of States having furnaces..... | 22 |
| No. of States making pig iron in 1872..... | 25 |
| No. of States making pig iron in 1873..... | 21 |

PRODUCTION OF PIG IRON IN 1872 AND 1873 BY STATES.

| STATES. | No. of stacks in blast Jan. 1, 1874. | No. of stacks built in 1872. | No. of stacks built in 18 | Whole No. of stacks in 1872. | Whole No. of stacks in 18 3. | Whole No. of stacks July 1, 1874. | No. of stacks building in 1874. | No. of stacks projected in 1874. | Make in 1872—Tons of 2,000 lbs. | Make in 1873—Tons of 2,000 lbs. |
|---|---|---|---|---|---|---|---|---|---|---|
| Maine | 1 | .... | .... | 1 | 1 | 1 | .... | .... | ..... | 780 |
| Vermont | 1 | .... | .... | 2 | 2 | 2 | .... | .... | 2,000 | 3,100 |
| Massachusetts | 5 | .... | .... | 6 | 6 | 6 | .... | .... | 17,070 | 21,13 |
| Connecticut | 8 | .... | .... | 10 | 10 | 10 | .... | .... | 22,700 | 26,977 |
| New York | 43 | 2 | 4 | 49 | 53 | 53 | 4 | 3 | 291,155 | 296,818 |
| New Jersey | 6 | 2 | 1 | 12 | 13 | 13 | 4 | 1 | 103,858 | 102,341 |
| Pennsylvania | 166 | 19 | 14 | 248 | 262 | 263 | 18 | 16 | 1,401,497 | 1,389,573 |
| Maryland | 17 | .... | .... | 22 | 22 | 23 | .... | 2 | 63,031 | 55,986 |
| Virginia | 13 | 2 | 3 | 32 | 35 | 36 | 4 | 1 | 21.445 | 26,475 |
| North Carolina | 3 | .... | 1 | 7 | 8 | 8 | 1 | 2 | 1,073 | 1,432 |
| South Carolina | .... | .... | .... | 8 | 8 | 8 | .... | .... | ... | ..... |
| Georgia | 6 | .... | 2 | 6 | 8 | 9 | 3 | 1 | 2,945 | 7,501 |
| Alabama | 7 | .... | 3 | 8 | 11 | 12 | 4 | 3 | 12,512 | 22,283 |
| Texas | ... | .... | ... | 1 | 1 | 2 | .... | .... | 619 | 280 |
| West Virginia | 5 | 1 | 1 | 5 | 6 | 6 | 3 | 3 | 20,796 | 23,056 |
| Kentucky | 16 | .... | .... | 25 | 25 | 27 | .... | 2 | 67,396 | 69,889 |
| Tennessee | 11 | 1 | 1 | 19 | 20 | 20 | 2 | 7 | 42,454 | 43,134 |
| Ohio | 65 | 6 | 5 | 83 | 88 | 88 | 8 | 9 | 399,743 | 406,029 |
| Indiana | .... | 2 | .... | 8 | 8 | 8 | .... | .... | 39,221 | 32,486 |
| Illinois | 1 | .... | 2 | 8 | 10 | 10 | 2 | .... | 78,627 | 55,796 |
| Michigan | 19 | 4 | 6 | 27 | 33 | 34 | .... | 6 | 100,222 | 123,506 |
| Wisconsin | 7 | 1 | 3 | 10 | 13 | 14 | .... | .... | 65,036 | 74,148 |
| Minnesota | .... | .... | .... | .... | .... | 1 | .... | .... | .... | ..... |
| Missouri | 10 | 1 | 4 | 14 | 18 | 18 | .... | 5 | 101,158 | 85,552 |
| Oregon | .... | .... | .... | 2 | 1 | 1 | .... | .... | ..... | ..... |
| Total | 410 | 41 | 50 | 612 | 662 | 673 | 53 | 61 | 2,854,558 | 2,868,278 |

Pennsylvania, with 262 stacks, makes very nearly one-half the pig iron made in the country. Ohio comes next, making one-seventh of the whole product with 88 stacks. New York, with 53 stacks, makes over one-tenth of the whole product. These three States and New Jersey make more than three fourths of the total product. Five Western "prairie" States, Indiana, Illinois, Michigan, Wisconsin, and Missouri, made 13½ per cent. of all the pig iron produced in 1872, and 12½ per cent. of all made in 1873. It is a singular fact that South Carolina has eight charcoal furnaces, and that not one of them was in blast in 1872 or 1873. The lack of capital to operate them, and the need of repairs, are assigned as the reasons for their long

suspension. Fuel and ore of an excellent quality are abundant in their vicinity, and it is scarcely possible that they will all remain much longer out of blast. Two other Southern States, Alabama and Georgia, are making rapid progress in the manufacture of pig iron, for which they possess truly wonderful facilities.

*Charcoal.*

| States. | No of stacks in blast Jan. 1, 1874. | No. of stacks built in 1872. | No of stacks built in 1873. | Whole No. of stacks in 1872. | Whole No. of stacks in 1873. | Whole No. of stacks July 1, 1874. | No. of stacks building in 1874. | No. of stacks projected in 1874. | Make in 1872—Tons of 2,000 lbs. | Make in 1873—Tons of 2,000 lbs. |
|---|---|---|---|---|---|---|---|---|---|---|
| Maine | 1 | .... | .... | 1 | 1 | 1 | .... | .... | ..... | 780 |
| Vermont | 1 | .... | .... | 2 | 2 | 2 | .... | .... | 2,000 | 3,100 |
| Massachusetts | 4 | .... | .... | 5 | 5 | 5 | .... | .... | 12,820 | 15,704 |
| Connecticut | 8 | .... | .... | 10 | 10 | 10 | .... | .... | 22,700 | 26,977 |
| New York | 14 | 1 | 2 | 15 | 17 | 17 | ... | .... | 19,812 | 29,329 |
| Pennsylvania | 28 | .... | 1 | 38 | 39 | 39 | .... | .... | 45,033 | 45,854 |
| Maryland | 12 | .... | .... | 14 | 14 | 14 | .... | .... | 29,044 | 30,315 |
| Virginia | 11 | 2 | 2 | 30 | 32 | 33 | 2 | 1 | 21,445 | 20,075 |
| North Carolina | 3 | .... | 1 | 7 | 8 | 8 | 1 | 1 | 1,073 | 1,432 |
| South Carolina | .... | .... | .... | 8 | 8 | 8 | .... | .... | ..... | ..... |
| Georgia | 6 | .... | 2 | 6 | 8 | 9 | 3 | 1 | 2,945 | 7,501 |
| Alabama | 7 | .... | 3 | 8 | 11 | 12 | 4 | 3 | 12,512 | 22,283 |
| Texas | .... | .... | .... | 1 | 1 | 2 | .... | .... | 619 | 280 |
| West Virginia | 3 | .... | 1 | 3 | 4 | 4 | .... | .... | 950 | 1,950 |
| Kentucky | 14 | .... | .... | 22 | 22 | 23 | .... | 2 | 39,699 | 42,219 |
| Tennessee | 10 | .... | .... | 17 | 17 | 17 | .... | 3 | 34,094 | 34,532 |
| Ohio — Hanging Rock | 33 | .... | .... | 33 | 33 | 33 | .... | .... | 87,440 | 92,365 |
| Ohio — Miscellaneous | 2 | .... | .... | 4 | 4 | 4 | .... | .... | 8,182 | 8,133 |
| Ohio — Total | 35 | .... | .... | 37 | 37 | 37 | .... | .... | 95,622 | 100,498 |
| Michigan | 18 | 2 | 6 | 22 | 28 | 29 | .... | 6 | 86,616 | 113,475 |
| Wisconsin | 6 | 1 | 2 | 8 | 10 | 11 | .... | .... | 27,790 | 38,880 |
| Minnesota | .... | .... | .... | .... | .... | 1 | .... | .... | ..... | ..... |
| Missouri | 8 | .... | 2 | 7 | 9 | 9 | .... | 2 | 45,589 | 39,536 |
| Oregon | .... | .... | .... | 1 | 1 | 1 | .... | .... | ..... | ..... |
| Total | 189 | 6 | 22 | 262 | 284 | 292 | 10 | 19 | 500,363 | 574,720 |

The production of charcoal pig iron increased nearly 75,000 tons in 1873 over the product of 1872, while there was a decrease in the production of both bituminous and anthracite pig iron. In each year named the quantity of anthracite pig iron produced was nearly one-half of the total product. The average annual product of the furnaces of the country, in net tons, is as follows: charcoal, 2,024 tons; bituminous coal and coke, 5,592 tons; anthracite, 6,435 tons.

There never having been any record kept of the quantity of pig iron on hand and unsold in this country, from year to year, it is obviously impossible to ascertain accurately the consumption of pig iron in any given year, but a very close approximation can be made by adding the production in that year to the quantity imported. Observing this method, we have the following results for 1872 and 1873:

| | |
|---|---|
| Home production of pig iron in 1872, net tons. | 2,854,558 |
| Pig iron imported in 1872, net tons ..... | 295,967 |
| Total consumption of pig iron in 1872, net tons | 3,150,525 |
| Home production of pig iron in 1873, " | 2,868,278 |
| Pig iron imported in 1873, " | 154,780 |
| Total consumption of pig iron in 1873, " | 3,023,058 |

In 1872 and 1873 our exports of pig iron to all countries (principally to Canada) were as follows: In 1872, 26,380 cwts.; in 1873, 180,436 cwts. A year ago much was

said in public journals of alleged shipments of pig and bar iron to Great Britain, but the most diligent inquiry fails to show that such shipments were ever made, although, as has heretofore been remarked, it is not improbable that English and Scotch founders will yet require large quantities of our charcoal iron for car-wheel purposes. This want, however, will not be created until the American method of making car-wheels becomes more popular in Great Britain than it now is. The British car-wheel, as at present constructed, is not composed, in whole or in part, of charcoal pig iron.

*Bituminous Coal and Coke.*

| States. | No. of stacks in blast Jan. 1, 1874. | No. of stacks built in 1872. | No. of stacks built in 1873. | Whole No. of stacks in 1872. | Whole No. of stacks in 1873. | Whole No. of stacks July 1, 1874. | No. of stacks building in 1874. | No. of stacks projected in 1874. | Make in 1872—Tons of 2,000 lbs. | Made in 1873—Tons of 2,000 lbs. |
|---|---|---|---|---|---|---|---|---|---|---|
| Penn. Shenango Valley | 15 | 5 | 2 | 29 | 31 | 31 | 2 | 1 | 160,188 | 160,831 |
| Penn. Allegheny County | 11 | 4 | .... | 11 | 11 | 11 | 1 | 1 | 110,599 | 158,789 |
| Penn. Miscellaneous | 18 | .... | 1 | 31 | 32 | 32 | 3 | 2 | 117,224 | 111,104 |
| Penn. Total | 44 | 9 | 3 | 71 | 74 | 74 | 6 | 4 | 388,011 | 430,634 |
| Maryland | 1 | .... | .... | 4 | 4 | 4 | .... | 2 | 12,079 | 5,264 |
| Virginia | .... | .... | .... | .... | .... | .... | 1 | .... | ..... | ..... |
| North Carolina | .... | .... | .... | .... | .... | .... | .... | 1 | ..... | ..... |
| West Virginia | 2 | 1 | .... | 2 | 2 | 2 | 3 | 3 | 19,846 | 21,106 |
| Kentucky | 2 | .... | .... | 3 | 3 | 4 | .... | .... | 27,697 | 27,670 |
| Tennessee | 1 | 1 | 1 | 2 | 3 | 3 | 2 | 4 | 8,360 | 8,602 |
| Ohio. Hanging Rock | 5 | 1 | 1 | 6 | 7 | 7 | 5 | 2 | 23,169 | 28,601 |
| Ohio. Mahoning Valley | 14 | 2 | 1 | 27 | 28 | 28 | .... | .... | 200,785 | 157,888 |
| Ohio. Miscellaneous | 11 | 3 | 3 | 13 | 16 | 16 | 3 | 7 | 80,167 | 119,042 |
| Ohio. Total | 30 | 6 | 5 | 46 | 51 | 51 | 8 | 9 | 304,121 | 305.531 |
| Indiana | .... | 2 | .... | 8 | 8 | 8 | .... | .... | 39,221 | 32,486 |
| Illinois | 1 | .... | 2 | 8 | 10 | 10 | 2 | ... | 78,627 | 55,796 |
| Michigan | .... | .... | .... | 3 | 3 | 3 | .... | .... | 13,382 | 795 |
| Missouri | 2 | 1 | 2 | 7 | 9 | 9 | .... | 3 | 55,569 | 46,016 |
| Total | 83 | 20 | 13 | 154 | 167 | 168 | 22 | 26 | 946,913 | 933,900 |

*Anthracite.*

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Massachusetts | 1 | .... | .... | 1 | 1 | 1 | .... | .... | 4,250 | 5,432 |
| New York | 29 | 1 | 2 | 34 | 36 | 36 | 4 | 3 | 271,343 | 267,489 |
| New Jersey | 6 | 2 | 1 | 12 | 13 | 13 | 4 | 1 | 103,858 | 102,341 |
| Penn. Lehigh | 30 | 3 | 3 | 44 | 47 | 47 | 6 | .... | 449,663 | 389,969 |
| Penn. Schuylkill | 26 | 3 | 3 | 37 | 40 | 41 | 4 | 4 | 232,225 | 236,409 |
| Penn. U. Susqueh'na | 14 | 3 | .... | 25 | 25 | 25 | 1 | 4 | 127,260 | 129,304 |
| Penn. L. Susqueh'na | 24 | 1 | 4 | 33 | 37 | 37 | 1 | 4 | 159,305 | 157,403 |
| Penn. Total | 94 | 10 | 10 | 139 | 149 | 150 | 12 | 12 | 968 453 | 913,085 |
| Maryland | 4 | .... | .... | 4 | 4 | 5 | .... | .... | 21,908 | 20,407 |
| Virginia | 1 | .... | .... | 1 | 1 | 1 | .... | .... | ..... | 4,000 |
| Total | 135 | 13 | 13 | 191 | 204 | 206 | 20 | 16 | 1,369,812 | 1,312,754 |

*Anthracite Coal and Coke.*

| States. | No. of stacks in blast Jan. 1, 1874. | No. of stacks built in 1872. | No. of stacks built in 1873. | Whole No. of stacks in 1872. | Whole No. of stacks in 1873. | Whole No. of stacks July 1, 1874. | No. of stacks building in 1874. | No. of stacks projected in 1874. | Make in 1872—Tons of 2,000 lbs. | Make in 1873—Tons of 2,000 lbs. |
|---|---|---|---|---|---|---|---|---|---|---|
| Wisconsin | 1 | .... | 1 | 2 | 3 | 3 | .... | .... | 37,246 | 35,268 |
| Michigan | 1 | 1 | .... | 1 | 1 | 1 | .... | .... | ..... | 8,736 |
| Total | 2 | 1 | 1 | 3 | 4 | 4 | .... | .... | 37,246 | 44,004 |

*Peat and Charcoal.*

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Michigan | . | 1 | .. | 1 | 1 | 1 | .. | .. | 224 | 500 |

*Charcoal and Bituminous Coal.*

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Virginia | 1 | .. | 1 | 1 | 2 | 2 | 1 | .. | ..... | 2,400 |

RECAPITULATION.

| | No. of stacks in blast Jan. 1, 1874. | No. of stacks built in 1872. | No. of stacks built in 1873. | Whole No. of stacks in 1872. | Whole No. of stacks in 1873. | Whole No. of stacks July 1, 1874. | No. of stacks building in 1874. | No. of stacks projected in 1874. | Make in 1872—Tons of 2,000 lbs. | Make in 1873—Tons of 2,000 lbs. |
|---|---|---|---|---|---|---|---|---|---|---|
| Charcoal | 189 | 6 | 22 | 262 | 284 | 292 | 10 | 19 | 500,363 | 574,720 |
| Bituminous Coal and Coke | 83 | 20 | 13 | 154 | 167 | 168 | 22 | 26 | 946,913 | 933,900 |
| Anthracite | 135 | 13 | 13 | 191 | 204 | 206 | 20 | 16 | 1,369,812 | 1,312,754 |
| Anthracite Coal and Coke | 2 | 1 | 1 | 3 | 4 | 4 | .... | .... | 37,246 | 44,004 |
| Peat and Charcoal | .... | 1 | .... | 1 | 1 | 1 | .... | .... | 224 | 500 |
| Charcoal and Bituminous Coal | 1 | .... | 1 | 1 | 2 | 2 | 1 | .... | ..... | 2,400 |
| Total | 410 | 41 | 50 | 612 | 662 | 673 | 53 | 61 | 2,854,558 | 2,868,278 |

Appended is a table showing the production of the various kinds of pig iron in the United States from 1854 to 1873, both years inclusive. It is compiled from statistics procured by this Association. Prior to 1854 no agency existed for the collection of the statistics of the iron trade, but in 1855 this Association was organized, and since then it has regularly collected and published these statistics. All that is definitely known of the progress of the iron industry in this country prior to 1854 is embraced in

a statement prepared by the Hon. Henry C. Carey, in 1849, and this statement we also append:

*Production of Pig Iron from* 1854 *to* 1873.

| Years | Anthracite. | Charcoal | Bituminous Coal & Coke. | Total. |
|---|---|---|---|---|
| 1854.. | 339,435 | 342,298 | 54,485 | 786,218 |
| 1855.. | 381,866 | 339,922 | 62,390 | 784,178 |
| 1856.. | 443,113 | 370,470 | 69,554 | 883,137 |
| 1857.. | 390,385 | 330,321 | 77,451 | 798,157 |
| 1858.. | 361,430 | 285,313 | 58,351 | 705,094 |
| 1859.. | 471,745 | 284,041 | 84,841 | 840,627 |
| 1860.. | 519,211 | 278,381 | 122,228 | 919,770 |
| 1861.. | 409,229 | 195,278 | 127,037 | 731,544 |
| 1862.. | 470,515 | 186,660 | 130,687 | 787,662 |
| 1863.. | 577,638 | 212,005 | 157,961 | 947,604 |
| 1864.. | 684,018 | 241,853 | 210,125 | 1,135,996 |
| 1865.. | 479,558 | 262,342 | 189,682 | 931,582 |
| 1866.. | 749,367 | 332,580 | 268,396 | 1,350,343 |
| 1867.. | 798,638 | 344,341 | 318,647 | 1,461,626 |
| 1868.. | 893,000 | 370,000 | 340,000 | 1,603,000 |
| 1869.. | 971,150 | 392,150 | 553,341 | 1,916,641 |
| 1870.. | 930,000 | 365,000 | 570,000 | 1,865,000 |
| 1871.. | 956,608 | 385,000 | 576,000 | 1,912,608 |
| 1872.. | 1,369,812 | *500,587 | †984,159 | 2,854,558 |
| 1873.. | 1,312,754 | ‡577,620 | §977,904 | 2,868,278 |

* Includes 224 tons of peat pig iron.

† Includes 37,246 tons of mixed anthracite and coke pig iron.

‡ Includes 500 tons of mixed peat and charcoal pig iron, and 2,400 tons of mixed charcoal and bituminous coal pig iron.

§ Includes 44,004 tons of mixed anthracite and coke pig iron.

*Mr. Carey's Pig Iron Statistics.*

In 1810 the whole number of furnaces in the Union was 153, yielding 54,000 tons of metal, equal to 16 lbs. per head of the population.

In 1821 the manufacture was in a state of ruin.

In 1828 the product had reached 130,000 tons, having little more than doubled in 18 years.

In 1829 it was 142,000 tons. Increase in one year, nearly ten per cent.

In 1830 it was 165,000 Increase in two years, more than 25 per cent.

In 1831 it was 191,000. Increase in three years, about 50 per cent.

In 1832 it was 200,000, giving an increase in three years of above 60 per cent.

In 1840 the quantity given by the census was 286,000, but a committee of the Home League, in New York, made it 347,700 tons Taking the medium of the two, it would give about 315,000 tons, being an increase in 8 years of 50 per cent.

In 1842 a large portion of the furnaces were closed, and the product had fallen to probably little more than 200,000, but certainly less than 230,000 tons.

In 1846 it was estimated, by the Secretary of the Treasury, at 765,000 tons, having trebled in four years.

In 1847 it was supposed to have reached the amount of not less than 800,000 tons.

In 1848 it became stationary.

In 1849 many furnaces being already closed, the production of the present year cannot be estimated above 650,000 tons; but from the accumulation of stock and the difficulty of selling it, it is obvious that the diminution will be greater.

In the 20 years ended with 1873, the growth of the pig iron industry of the United States, as compared with that of the United Kingdom of Great Britain, was as follows. The ton used in the statistics of the United Kingdom is the gross ton of 2,240 lbs.; that used in the statistics of the United States is the net ton of 2,000 lbs.

| Year. | U. King. Tons. | U. States Tons. |
|---|---|---|
| 1854 | 3,069,838 | 736,218 |
| 1855 | 3,218,151 | 784,178 |
| 1856 | 3,586,377 | 883,137 |
| 1857 | 3,659,477 | 798,157 |
| 1858 | 3,456,064 | 705,094 |
| 1859 | 3,712,904 | 840,627 |
| 1860 | 3,826,752 | 919,770 |
| 1861 | 3,712,390 | 731,544 |
| 1862 | 3,943,469 | 787,662 |
| 1863 | 4,510,040 | 947,604 |
| 1864 | 4,767,901 | 1,135,996 |
| 1865 | 4,819,254 | 931,582 |
| 1866 | 4,523,897 | 1,350,343 |
| 1867 | 4,761,023 | 1,461,626 |
| 1868 | 4,970,206 | 1,603,000 |
| 1869 | 5,445,757 | 1,916,641 |
| 1870 | 5,963,515 | 1,865 000 |
| 1871 | 5,627,179 | 1,912,608 |
| 1872 | 6,741,929 | 2,854,558 |
| 1873 | 6,850,000 | 2,868,278 |

The value of the pig iron product for any year can be approximately ascertained by multiplying the average market value throughout the year of each kind of iron by the year's product, and adding the results thus obtained. In this manner we have carefully calculated the value of the pig iron manufactured in this country during the years 1872 and 1873, and find it to be as follows:

| | |
|---|---|
| Value of 2,854,558 net tons of pig iron produced in 1872 | $132,649,621 |
| Value of 2,868,278 net tons of pig iron produced in 1873 | 118,243,308 |

In 1854 the production of anthracite pig iron overtook that of charcoal, and in 1869 the production of charcoal pig iron was again overtaken by that of bituminous coal and coke. Since 1854 anthracite has been the leading branch of our pig iron industry, and since 1869 charcoal has been the least productive of all branches.

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The old iron mine in Salisbury, Ct., which has been worked over one hundred and fifty years, recently declared an annual dividend of one hundred and fifteen per cent.

# THE CHANNEL TUNNEL.

From "Nature."

We fear there are still many who fail to see that any good can come of scientific research unless it has some well-defined "utilitarian" object in view. Even in this and in other countries that are in the van of civilization, and in which education is comparatively wide-spread, the majority of mankind can appreciate a benefit only when it takes a concrete and tangible form. That love of knowledge for its own sake, that noble inquisitiveness which has been so fruitful in results during the last two hundred years, even yet belongs to comparatively few, who are still regarded by the many with a kind of impatient pity as mere unpractical hobby-riders. Still the people who talk in this way are proud enough of the glory which their great men have shed upon their country, and would not willingly, we believe, part with it for money, were this possible; and, indeed, how would this country appear among the nations, were she deprived of the inestimable inheritance which her great sons have bequeathed to her in every department of intellectual activity? Happily, however, the race of those who decry single-eyed scientific research is getting sensibly smaller; and we firmly believe that as education improves, and as higher education spreads, carrying with it the results of this same scientific research, it will disappear.

Still, a little consideration might show those who are ever ready to cry "what's the good?" that since all so-called "practical" schemes are concerned either with man's own body or with the surrounding universe, an essential part of the basis of any scheme is a thorough knowledge of the material on which it is proposed to work. Such a knowledge it has over and over again been shown, is only to be attained by abstract scientific research, by investigation conducted as if the only end in view were a thorough knowledge of the subject in hand, in all its scientific aspects and relations. Many instances could be given, and indeed are every day occurring, of the highest practical results unwittingly following from such investigations; and to the skeptic we could not recommend a better example of how indispensable is thorough scientific research as a basis for the useful arts than the results of the investigation into the geology of the Channel, which Mr. Prestwich (the newly elected Oxford Professor of Geology) presented to the Institution of Civil Engineers last December, and which, with the subsequent discussion and maps, has just been published in a separate form. This study of the strata which underlie the Channel, and which seems to us an almost perfect example of close and careful reasoning on physical facts, is now brought forward to enlighten the projectors of a tunnel between England and France as to the nature of the material with which they will have to work; but Mr. Prestwich distinctly states that the various formations are considered "irrespective of their relative merits in any other than a geological point of view."

Mr. Prestwich's plan is to discuss carefully all the strata which underlie the Channel, from the London clay down to the Palæozoic series, exhibiting distinctly their lithological characters, dimensions, range and probable depth, and from these data deducing his conclusions as to the suitability of each formation for being pierced by a tunnel. The investigations of himself and others, on which Mr. Prestwich's paper is founded, were mostly undertaken from no practical point of view, and before a Channel Tunnel was thought of. Mr. Prestwich, many will be glad to think—grateful, we hope at the same time, for this very practical result of pure scientific research—concludes that from a geological point of view it is quite practicable to construct a tunnel underneath the Channel, although to do so with safety it will be necessary to go very deep down. But an excellent idea of the results of the investigation will be obtained from the following clear summary with which Mr. Prestwich's paper concludes:

"In the London clay there exists a perfectly impermeable bed of sufficient thickness, but nowhere between the two countries, except probably at points where the distance presents apparently insuperable difficulties. The lower chalk, or chalk marl, affords a comparatively impermeable deposit, also of sufficient dimensions; but from its having a calcareous base, and from the possibility of fissures, with the absence

of a protecting overlie, it has great uncertainty. In the gault there is another impermeable stratum, but of dimensions too small. The lower green-sand contains no beds sufficiently continuous and impermeable. The Weald clay ranges about halfway across the Channel; and if a belt of it should possibly pass round at the north end of the Varne and range to Wissant, it might prove to be worth further inquiries. In the Kimmeridge clay there is again a deposit of sufficient dimensions, but with a subordinate band which may be sufficiently permeable to present difficulties, while, though it comes to the surface on the French coast, its depth on the English coast must be very considerable. There is, however, just a chance that the Kimmeridge clay may in mid-channel be overlapped unconformably, and at a slight angle, by the Weald clay, and in that case they might for all purposes be considered as continuous strata. The Oxford clay presents similar difficulties, in addition to its greater depth and inaccessibility. In the secondary strata, the irregular lie of the strata, and the presence of faults, are contingencies important to be considered.

"On the other hand, the great mass of the Palæozoic rocks, so protected by impermeable overlaying strata, is of such great dimensions, and so compact, and holds its range so independently of the more irregular range of the secondary strata, that it offers the conditions most favorable for the secure construction of a submarine tunnel; and that such strata can be worked in safety, and for considerable distances under great bodies of water, has been proved at Whitehaven and Mons. But, on the other hand, the depths of these old rocks below the surface is very great, and they are much more dense and harder than the overlying formations.

"There is another important problem in connection with the Palæozoic rocks which such an undertaking might help to solve. The great question of the range of the coal measures under the south of England has lately come prominently into notice; and it was, in fact, in inquiries connected with that question that the foregoing considerations presented themselves to the author. The rich coal basin of Mons and the north of France has been traced to within 30 miles of Calais, where it thins out; but, like the coal basins of Liege, Aix and Westphalia, which form separate sections of the same great trough, to the eastward, so there is reason to suppose that other sections of the trough set in on the westward, forming other coal basins, which possibly range to the west of England (Somersetshire), passing under the north-eastern part of Kent and the Thames. Any such work, therefore, as a submarine tunnel in these Palæozoic rocks could not fail to throw much light on the subject; while, in case it were to hit upon the line of strike of the coal measures, and could be carried on along that line, the work might prove otherwise remunerative, and tend to solve the great problem which interests so largely both geologists and the general public.

"Such, briefly, are the conditions which bear on the construction of a submarine tunnel between France and England. The author is satisfied that, considered on geological grounds alone, it is in one case perfectly practicable, and in one or two others it is possibly so; but there are other considerations besides those of a geological nature, and whether or not they admit of so favorable a solution is questionable. In any case the author would suggest that, the one favorable solution admitted, it may be desirable, in a question involving so many and so great interests, not to accept an adverse verdict without giving to all those other considerations the attention and deliberation which the importance of the subject deserves.

"Under any circumstances, the difficulties are formidable. Whether or not they are insuperable are questions which may safely be left to civil engineers. The many and great obstacles overcome by engineering science in late years lead the author to expect that, should the occasion arise, and the attempt be considered worth the cost, the ability to carry it out would not be wanting. Various preliminary trials are, however, indispensable, in order to clear up some of the geological questions, before a balance of the comparative advantages presented by the different formations could be satisfactorily settled, and before the grounds for action could be accepted."

From this it will be seen that the possibility of a Channel Tunnel remains now only with the engineers to decide. Geology has told them all the natural conditions under which they will have to work, so far as these can be known without actually tunnelling; and since so cautious a reasoner as Mr. Prestwich thinks it possible to carry out the scheme from a geological

point of view, we should think that if it could be proved that the undertaking would pay, our engineers would be eager to show that the resources of their art are quite equal to its successful accomplishment.

## REPORTS OF ENGINEERS' SOCIETES.

MANCHESTER STEAM USERS' ASSOCIATION—CONTEMPLATED BOILER EXPERIMENT.—From the chief engineer's report of this association, we learn that it is intended to carry out some experiments for the purpose chiefly of obtaining information as to the weakness in boilers due to the openings cut for manholes, etc. We cannot do better than reproduce Mr. Lavington Fletcher's programme :—

"Those at all conversant with the association's monthly reports must have observed how many boilers have given way through the weakening effect of the manhole on the cylindrical portion of the shell, a fact to which boiler makers do not seem to have attached sufficient importance, or at all events till very recently. Those manholes from which the explosions recorded have arisen, have been unguarded, but the question remains whether the mouth-pieces now adopted for strengthening them are sufficient for the high pressures coming into such general use, and also how safety may be attained without unnecessary expenditure. In a well-constructed boiler the flue tubes are so well armed against collapse, and the flat ends so well stayed, that the weakest part of the structure is the cylindrical shell, and if this be double riveted, then the weakest part of the whole boiler is the manhole or other similar opening. This is apparent on a consideration of the strains, and is very frequently exemplified practically on the application of the hydraulic test. On such occasions cast-iron manhole mouthpieces not infrequently give way, and the boilers sometimes rip open on the top in a longitudinal direction. In one case a steel boiler though strengthened with a wrought iron manhole mouthpiece rent on each side of its longitudinally. Boilers also exhibit distress at the base of the steam domes, and in some recent experiments made in America to test the strength of boilers by bursting them under steam pressure the boiler was found to give way at that part. The association has always been alive to this weakness, and has for many years induced its members when laying down new boilers, to dispense with steam domes altogether. Many boilers, however, have openings cut in them at the base of steam necks, which are very similar to manholes in size, but are not by any means equally strengthened. These necks are sometimes planted on the top of boilers as much as 7 feet in diameter, and worked up to 70 or 80 pounds. They are inherent also in the construction of the French or elephant boiler, and many others now introduced for working steam at high pressures. Such boilers are sometimes placed in the basement of very lofty buildings, so that in the event of an explosion the results would be most serious. It is thought, therefore, that no uncertainty should be allowed to exist as to the effect of these openings on the strength of cylindrical boilers worked at high pressures, and therefore it is proposed to construct an experimental boiler for the purpose of testing these necks and manhole mouthpieces by hydraulic pressure carried up to the bursting point.

"In the first instance it was proposed to construct a small cylindrical egg-ended boiler, say 5 feet 6 inches in diameter, and to plant such necks and mouthpieces upon it as it was thought to be desirable to test. On further consideration of the subject, however, it appeared that the experiment would be of far greater value if extended to a Lancashire boiler of ordinary working proportions, though its length might be somewhat shorter. In this way the precise diameter adopted in everyday practice, and also the precise thickness of plate, could be tested as well as the actual patterns in use for manhole mouthpieces, etc., which would afford more direct, and thus more satisfactory conclusions. Further than this, the adoption of an experimental boiler of the Lancashire type would allow the opportunity at the same time of testing the strength of the furnace tubes both as regards collapse and elongation, as well as of testing the flat ends with their gussets and longitudinal stays, and also the cylindrical shell at the longitudinal seams of rivets. Such a test would be most complete, and, after the disastrous explosion at Blackburn, would, it is thought, be of considerable practical value.

"With this view it is proposed to construct a Lancashire boiler, having a length of 21 feet, a diameter in the shell of 7 feet, and in the furnace tubes of 2 feet 9 inches, the longitudinal seams being double riveted, the front end plate attached with an external angle iron and the back with an internal one, and both strengthened with substantial gussets and longitudinal bolt stays, the thickness of the plates seven-sixteenths in the cylindrical portion of the shell, three-eighths in the furnace tubes and ½ inch in the flat ends. The reason for the length of the boiler is as follows :—It is important that the belt of plating on which the manholes and necks to be operated upon are placed should be free from all bias, and therefore it is proposed to plant the manholes, etc., on the belt of plating midway between the two ends of the boiler, and further to allow a free belt on each side of this one, so that it may not in any way be strained or affected by the action of the gussets. This involves a length of three belts of plating, and as the gussets occupy two belts of plating at each end, that involves seven belts together, and as these are 3 feet wide, it makes up the length of 21 feet. This length may at first sight appear considerable, but it will add to the value of the experiment not only as regards the shell but also as regards the collapsing tendency of the flue tubes, while it would not materially increase the expense of the experiment.

"The general outline of the experiment it is proposed should be as follows :—In the first place plant on the top of the central belt of plating a wrought iron neck of such a thickness and diameter as is now met with in boilers under inspection, viz., from 15 to 16 inches in diameter, seven-sixteenths of an inch in thickness, and attached to the boiler by a single line of rivets, the neck being blanked up at the top with a cover. This being done the hydraulic pressure to be applied and carried on until the plate bursts. The pres-

sure to be increased steadily, and meanwhile the behavior of the boiler to be carefully watched and measured. The furnace tubes to be gauged internally in the direction of their diameter to see if any tendency to collapse is discernible, and also gauged longitudinally to see if any extension of the flanged seams takes place. The flat ends to be tested both with and without the longitudinal bolt stays and gauged under both conditions at a number of points, so that their behavior may be ascertained. The wrought iron neck or manhole mouthpiece, as the case may be, to be gauged longitudinally and transversely to see what change of form takes place under the strain put upon it by the shell, and further, to ascertain the strain put upon the plates around the opening, a number of parallel lines to be inscribed upon the plate in a longitudinal direction before the pressure is put on, when it is expected that they will curve or bulge outwards away from the manhole on the application of the test. The amount of curve will no doubt much depend on the character of the plates.

"When the first neck has burst it would then be replaced with such other necks and manhole mouthpieces as it was thought desirable to test, the belt of plating also being renewed as occasion might require. As it is proposed that the central belt of plating should be an external one, renewing one of the plates on this belt as often as was necessary would not be a matter of much difficulty.

"There are many other points to which it would be worth while to direct attention, which will suggest themselves on further consideration, but the above is just an outline for the consideration of the committee."

NOTE.—At the meeting at which the report was read, the committee took into consideration the above proposition to construct an experimental boiler to be tested with water up to the bursting point, and resolved to carry it into operation at once.

THE ASSOCIATION OF MUNICIPAL AND SANITARY ENGINEERS AND SURVEYORS

The Annual Meeting of the Members of this Association was held in the Council Chambers, Birmingham, on Thursday, the 28th ult., and following days. The annual report showed that the progress of the Society during the past year had been most encouraging.

The President (Mr. Lewis Angell) then delivered his inaugural address. After congratulating those present upon the success which had attended their efforts to establish the Association, he said they had united the scattered members of a special branch of their profession, and created an *esprit de corps*; already they had a history and an influence.

Mr. C. Jones, the secretary, then delivered an address on "Sanitary Legislation and its Practical Exponents." In the course of it he referred to the employment of officers under the title of "Inspectors of Nuisances" to carry out the provisions of the Sanitary Acts.

Mr. E. B. Ellice Clarke, of Ramsgate, then read a paper on "Sewage Ventilation," in which he stated that the evidence he had obtained from nearly 100 towns showed a deplorably backward state of things as regarded the actual ventilation of the sewers. The conclusion he came to was that by far the most effective system yet adopted was the simple one of open gratings in the centre of the street. Crude it might be yet it had well answered its purpose, and it possessed many advantages over any system that had been attempted to deodorize the gases. It was not liable to get out of repair, and from its entire simplicity, was unquestionably superior to any other mode in diluting and dispersing the gas. With modification, he believed it to be the only way of ventilating our sewers.

Mr. E. Monson followed with a paper on "The Sewage Difficulty; including the value and purification of sewage, farmyard, and artificial manures," which went to prove that as there was no demand for sewage, there was much difficulty in disposing of it, and as the result claimed for it might also be claimed for irrigation, sewage could not be utilized at a profit if it had to be pumped, but it might pay its expenses if utilized by gravitation, and that the attention of town authorities should be directed to its purification by filtration, and by utilization to a limited extent, as these required less land, and did not entail so much expense.

The President read a paper on the general subject. Mr. Prange described Whitthread's process, which consists "in adding dicalcic phosphate, dissolved in an aqueous solution of monocalcic phosphate, to the sewage as it flows from the sewers, and when the whole was well mixed, in adding milk of lime in sufficient quantities to precipitate all the phosphates, avoiding an excess of lime."

Dr. Anderson gave a sketch of the Sulphate of Alumina process which he is carrying out at Coventry, and which he expects will pay expenses and yield a profit.

Colonel Jones, V. C, read a paper on his mode of treating the sewage of the small town of Wrexham. Descriptions were afterwards read of the Phosphate process by Mr Tanner, of the Cement process by Major-General Scott, C. B., and of Milburn's process. Dr. Wilson, the Medical Officer of Health, said that many of the processes had been made Stock Exchange speculations, and had not therefore been put before the public so honestly as they might have been. Looking at the question from a purely medical point of view, he believed the water carriage system was the best system, and he had no hesitation in recommending the adoption of water-closets in all towns where there was a good water supply.

Subsequently Mr. T. A. Skelton read a paper upon "Gas Street Lighting," which described his Catropric lamp.

On Saturday the proceedings of the meeting were brought to a close by an inspection of the sewage works at Saltley, belonging to the Birmingham Corporation.—*Architect.*

## IRON AND STEEL NOTES.

SLAG AS A BUILDING MATERIAL.—Mr. W. F. Hooper, Professor of Architecture and Building Science, Royal Polytechnic College, London, has published a letter on this subject. He says:—

"It is a matter of astonishment to me that colliery owners and others, who have such enormous quantities of this waste material at their command, have not utilized it to a much greater extent. In

it they have the most valuable material that it is possible to obtain for erecting the class of buildings they require; and yet they not only treat it as a waste, but they cover acres of valuable land as a shoot in order to get rid of it.

"As I have planned and superintended the erection of hundreds of buildings in concrete in different parts of the country during the last ten or twelve years, and have constantly used slag as an aggregate wherever I could procure it, perhaps a few facts from me respecting my experience of its use might be not uninteresting.

"It is now a well-known and established fact that where good aggregates, such as slag, gravel, broken sandstone, furnace ashes, or other hard material free from loam or clay, can be procured to combine with cement, concrete buildings are not only the cheapest but the most durable that can be erected. They are the cheapest because no skilled labor is required in their erection, so that the annoyance arising from the strikes of masons is avoided, and their durability has been fully proved, many having stood from time immemorial. But these are by no means the only advantages of concrete. Stone and brick, the ordinary building materials of this country, are more or less porous, and absorb not only a vast amount of moisture during wet weather, which requires weeks of fine weather or tons of fuel to evaporate, but they also absorb the animal gases, and in cases of epidemic are a main cause in the spread of disease. Now, with concrete this absorbent property is reduced to a minimum, as has been fully proved by erecting cisterns made of the material and although placed over the ceilings of rooms where the slightest leakage would be discernible, no damp has appeared. Thus for flat roofs it is invaluable, and its strength and tenacity are such that it can be used to cover large surfaces with but slight support.

"As I said before, slag is the very best material to use with cement for these buildings. Having been subjected to intense heat, all particles of loam, or clay, etc., that would tend to kill the cement and render the work rotten, have been removed, and its rough, honeycombed character forms a perfect key in the work. About two-thirds the quantity required should be broken either by machine or hand to the size of walnuts, with sufficient of smaller to fill up the cavities between; the remaining one-third should be used in lumps (but not larger than two-thirds the thickness of the wall), and packed in layers in the centre of the wall, the smaller, mixed with cement in the proportion of eight to one, being poured round."—*Architect.*

VALUE OF IRON WASTE.—A very important but, until quite recently, neglected constituent of the waste-heap are the old iron, battered saucepans, old pails, rusty hoops, horse shoes and nails from the road. All soldered articles have the solder extracted from them, as it is more valuable than the iron, and the cheaper metal is then melted. The horseshoe nails are not mixed with the common cast-iron, as they are much sought after by gun-makers for the purpose of making stub-twist barrels. Scraps of iron, it is found, may be made very useful in securing the copper in the streams washing veins of copper pyrites. Pieces of battered iron ore placed in tanks, into which these are collected: the copper, under these circumstances, incrusts the iron, and, in process of time, entirely dissolves it, so that a mass of copper takes the place of the iron, and the residuum, in the shape of a colored deposit, is at times taken out, dried and smelted. Thus, from the merest and apparently worthless waste, a large value is realized.—*Railway Register, St. Louis.*

THE total amount of pig iron made by the furnaces of Milwaukee in 1873, was 35,123 tons, about 500 tons less than the amount estimated at the beginning of the year. The total product of all the furnaces of Wisconsin was 73,983 tons

The contracts for the building and machinery of a new rolling mill at Milwaukee, Wis., for the Milwaukee Iron Company, are already let, and it is expected to have the new establishment in full operation by the 1st of September next. The main building will be of brick and iron, 80 by 216 feet and the capacity of the mill is estimated at 50 tons of bar iron per day. The company enters upon this new enterprise with every assurance of success, and it cannot be doubted that its advent marks a new era in the manufacturing industries of Milwaukee. It is the only link that has been wanting in the chain of facilities afforded by Milwaukee for the successful prosecution of iron manufactures of every description.

Ground has been broken for an iron furnace at Hackettstown, N. J., between the railroad and canal, twenty acres having been set apart for it. The furnace is to be fifteen feet bosh, stack fifty-five feet, and will have a 400 horse power engine. It will be capable of turning out from 200 to 225 tons of iron per week.—*Engineering and Mining Journal.*

## RAILWAY NOTES.

THE FASTEST TRAIN ON THE CONTINENT.—Probably the best specimen of an American highway to be found anywhere is the Pennsylvania Railroad, between Pittsburgh and New York. In solidity of construction, superiority of bridge architecture, and smoothness of track, it is unrivalled. Throughout its entire length it is laid with a double track of 60-lb. steel rails, fastened on oak ties, imbedded in broken stone ballast, with splice-joints between the ties, and so arranged that the connection on one side comes opposite to the centre of the rails on the other. The rolling stock is as near perfection as human ingenuity and skill has been able to make it. Locomotives and cars are alike built by the company at their own shops, and in the details of materials, design and finish, combine the highest excellence attainable. To all this is added a rigid policy of management, exacting the utmost care and courtesy from employees of every grade, and the application of those effective safeguards—the Westinghouse air-brake and the block-signal system—showing that whatever can be done for the safety of travelers has been done on this great line of railway. This high standard of excellence having been reached, the managers feel warranted in taking another advance step for the special benefit of through travel, and the 1st of June commenced running a fast daylight train from Pittsburgh to Philadelphia and New York,

with close connections at Harrisburg for Baltimore and Washington, on the following schedule:

| | |
|---|---|
| Leave Pittsburgh 7:25 A.M. | Arrive Baltimore 6:55 P.M. |
| " Altoona...11:28 " | " Washington 9:02 " |
| " Harrisburg 3:25 P.M. | " Philadelphia 6:40 " |
| | " New York... 9:30 " |

The magnificent run of 444 miles is made with but three stoppages—the first, of only 5 minutes at Altoona, after a stretch of 117 miles; the second of 20 minutes for dinner, at Harrisburg, after an unbroken dash of 132 miles, and the third and last, of only 5 minutes at Philadelphia, after a run of 105 miles, leaving a single stretch of 90 miles across New Jersey to destination. No time being lost in stopping, the wonderful locomotive engines work away with the regularity of fixed machinery, taking their supply of water from the track tanks as they go, and carrying their fuel with them; and the time is made by uniformity of progress more than by an increased speed. The train is made up of Pullman parlor cars and the best of the Company's day coaches, all splendidly upholstered, mounted on combination springs, and furnished with plate-glass windows, through which the landscape can be distinctly seen. And here comes in the great charm of this daylight ride through Pennsylvania, for the train leaves Pittsburgh at 7:30 in the morning and reaches Philadelphia at 6:45 in the evening. On, on, on, goes the tireless train, over a clear track, carrying the traveller by a panorama, the like of which can be found nowhere else on this continent, and probably not in the world. After having breakfasted in Mississippi Valley and dined at the capital of Pennsylvania, the passenger finds himself at supper in the metropolis of New York. A few years ago a man who would have predicted such a ride would have been pronounced hopelessly insane. But it is a fact accomplished—a reality of the day, and all that is left for the people is to wonder and enjoy.—*Pittsburgh Commercial.*

SHALER'S COMBINATION SIGNAL AND FLASH-LIGHT.—This article is the very best of its kind in existence, and should be on board of every kind of vessel, steam or sail. It is the perfection of the lantern and flash signal. It is simple, safe, reliable and inexpensive, and its universal adoption and use would unquestionably be the means of saving many lives and much property. Its value consists in part: 1st. As an ordinary lamp or lantern. 2d. As a convenient danger or telegraphic signal, always ready and at hand in case of accidents, alarms, fogs, or threatened collisions. 3d. As a powerful illuminator in dark nights, rendering the smallest objects visible for many yards distant in all directions.

It has received the warmest commendations from all who have ever seen its operations. It is adopted by the Board of Supervising Inspectors of Steamboats, by the Navy Department, Life Saving Service, Coast Survey, &c. The Committee of the Board of Supervising Inspectors report upon it as follows: "It is a simple contrivance, and its effect as a Signal Flash Light is perfection itself." The invention is an improvement on Signal Lanterns for Railroads, and is equally useful wherever flash lights are required. It is an ordinary lantern, in which lard or sperm oil is used, with a separate reservoir containing naphtha or volatile oil held in suspension by cotton batting packed in a wire gauze sack, and by means of a cylinder or air-tube passing through said reservoir common air is injected and forms with the volatile oil hydro-carbon gas, that escapes through a tube adjoining the fixed light, creating thereby a brilliant flame a foot or more in length, and visible for a very long distance.

In connection with this invention, known as the Shaler Combination Signal and Flash Light, is a can, represented to be entirely safe, for the transportation of naphtha, it being provided with shields to its apertures of wire gauze, acting on the principle of the Davy lamp.

TRIAL OF A HYDRAULIC BRAKE.—A trial of the Henderson patent hydraulic brake was made on the West Chester and Philadelphia Railroad, July 21, and is thus reported by the Philadelphia *Ledger:*

"The train consisted of five passenger cars and one baggage car, attached to a large and powerful locomotive. It left the depot at 11 o'clock, and ran about ten miles up the road, during which several stops were made, and the workings of the brake thoroughly tested. The first stop was made on a grade with a descent of 15 feet to the mile, running at a speed of 35 miles per hour, when the train was stopped in a distance of 630 feet and in 20½ seconds time, with a boiler pressure of 105 pounds to the square inch. The second was made on a grade of about the same inclination, at a speed of 32 miles, and in a distance of 540 feet, at a boiler pressure of 115 pounds to the square inch. The third stop was on a level, at a speed of 35 miles an hour, and was made in 840 feet, in 28½ seconds time, with a boiler pressure of 105 pounds to the square inch. This stop was made by bell signal from the rear end of the train.

"The brake is under the control of and is worked by the engineer of the locomotive. The following description will give an idea of the manner of its operation. Between the wheels of each truck there is placed a cylindrical vessel of cast iron, whose ends are formed of two dish-shaped flexible diaphragms of India-rubber, secured to the drum, and making an air-tight joint at the periphery by flanges bolting thereto. Two rams working in opposite directions are fitted against and into the hollow part of the diaphragms, their outer ends are attached by rectangular flanges and bolts to the brake-beams carrying the brake-shoes. The several castings are simply bolted together, with the diaphragms, as they come from the foundry, without recourse to the usually expensive mechanical fittings.

"When pressure comes between the diaphragms, it simply forces them apart, projecting the rams, which act immediately on the brake-beams, applying the brakes; and when the pressure is relieved the atmosphere reacts on the area of the rams and forces them back, assisted by the tendency of the diaphragms themselves to recover their normal condition."

## ENGINEERING STRUCTURES.

WORK ON THE GOSCHENEN SIDE OF THE ST. GOTHARD TUNNEL was advanced 82 metres during May, and on the Airolo side by about 45

metres; total 127 metres. By the end of May, 1823.40 metres altogether were accomplished, and on the 8th inst. 1840 metres. The progress at the Goschenen side was very satisfactory, considering the continuing hardness of the rock. In consequence of an accident by which several men were killed, the works were for a time almost interrupted, having a considerable influence on the advance of the work. An investigation has shown that the accident was due to a want of caution on the part of the unfortunate men. The three wounded are reported almost out of danger. On the Airolo side the works are very much hindered by the great influx of water. The low result of last month is, however, also attributable to sickness among the more skilled workmen and to the extraordinay tenacity of the rock, which resists sometimes even dynamite. The hornblende and gneiss formation encountered, though it was calculated that they would be met with, are not of great thickness, but they will be struck again. The results obtained during the last week of the month where somewhat better, and there is no reason for supposing that in Airolo also better progress will not soon be made. By the end of this month a sufficient number of the improved McKean boring machines, at present only partially employed, will be ready, and they will then be exclusively employed in the works of the tunnel.

ANOTHER DETROIT TUNNEL PROPOSITION.—The Detroit Board of Public Works have received a letter from Jerome Wenmacker, a French inventor, in New York, in which he makes a proposition to construct a tunnel under the Detroit River. His system is to pass under the stream with the crest of the tunnel nearly level with the bed, rendering the approaches shorter and less abrupt than they usually are; the depth of the water or the nature of the soil is of no consequence, and when the work is well organized it can be carried forward with greater rapidity than any work of similar magnitude on land can be. His plan embraces one coffer dam on each side, and two more at equal distances from the side dams further out. At each of these he would sink a shaft to the tunnel bed, and put on six gangs for the excavation. The earth, etc., could be taken out at the nearest shaft and the materials for construction passed through the same. The tunnel would have a flat bed, a semi-circular arch being constructed of masonry with buttress supports on each side. The cost for two tracks would, according to Mr. W.. be about $600 per running yard, and for a 4-track tunnel about $1,000 per yard.

A NEW THAMES TUNNEL.—At a special meeting of the Greenwich District Board of Works, Mr. T. Norfolk presiding, Mr. Barlow, of Charlton, who was largely engaged in the engineering arrangements of the Midland lines of railway, attended to explain the details of a scheme to provide a road and railway communication from East Greenwich, across the marshes, to Blackwall Point, and thence straight across the river by a tunnel to Poplar, thus forming a direct communication from the East India Dock Road, on the north side of the river, to the Woolwich and Greenwich Road, on the south side. By means of a section he had prepared, it was shown that the relative level of the river and the land is peculiarly favorable for the construction of approaches to a tunnel passing under the Thames at the place proposed. The general gradient would be 1 in 40, and the length of the tunnel 600 yards. He called attention to the fact that east of Tower Hill there is no place where a crossing could be effected without involving the necessity of passing over or under existing docks or dock communications, except the point selected; and that eastward of this point the East India and Victoria Docks occupy the ground for such a further length of the river-side that a communication eastward of them would be of comparatively little value. Mr. Barlow stated, as his opinion, that a tunnel of substantial build, and of dimensions suited to the large and important traffic which would pass through it, might be constructed at a cost less than the average cost of the bridges in the metropolitan area above London Bridge. The cost of the work would necessarily be affected by the dimensions, a subject which would have to be determined by the Metropolitan Board of Works and their engineer. Mr. Barlow then said that the project, so far as he had described it, was a public road, but it happened that the same plan of crossing the river might also be used for railway purposes. On the north side there were five railway companies—the London and North-Western, the Midland, the Great Eastern, the Great Northern, and the North London—and there was a point on the railway near Canning Town, on the line owned by the Great Eastern, where all these companies had running powers; so that, by making a second tunnel for railway purposes, and uniting it to the Great Eastern system at this one point, the whole of the five railway companies could be brought across the river and obtain direct access to Greenwich, Woolwich, &c., and also unite with the South-Eastern system. Mr. Barlow stated that until the subject was fully reported upon he was not prepared to speak definitely as to cost, but his impression was that, if the Metropolitan Board of Works made the road by itself, the cost would be from £500,000 to £600,000, but that, if it was made jointly with a railway tunnel, its cost would be from £400,000 to £450,000. He believes it would be advantageous to the railway companies to take advantage of such an opportunity of obtaining a crossing of the river at this point. In requesting the earnest atention of the Board to this proposed communication, he did so in the full conviction that, if the Metropolitan Board of Works constructed it as a free highway, its cost would be amply repaid by the increased value given to a large area of property, by the saving of the expense of transport of a great amount of goods and merchandise now compelled to go round by London Bridge, by facilitating the intercourse between the northeast and southeastern districts of the metropolis, and by diminishing the delays and obstructions to the general traffic of London Bridge and several miles of streets.

## ORDNANCE AND NAVAL.

THE POLYSPHERIC SHIP.—Mr. Charles Meade Barnes has produced a new kind of ship, which he calls the Polyspheric. The bottom is flat, and fitted with three inclined planes with square ends,

the effect being as though three tenths of a gigantic saw were moved through the water with the sloping portion of the teeth first. The intention is to lift the hull out of the water. Mr. Barnes thus describes the experiments he has made with his model:—"The first of the experiments was made with a 7 lb. model. This model was by the propelling power driven forward over the water 66 yards in 6 seconds, the rocket in that time having been completely discharged, and the model brought to a state of rest on the water. The average speed observed in this case was 33 ft. in a second, or about 20 knots an hour, but it may be assumed that at its greatest, the speed could not have been less than 25 knots an hour. The second experiment was made with a model of similar form, but of slightly different proportions, and weighing with the full rocket 3 lb. 3 oz. The distance run in this case was 105 yards, and this distance, the time being carefully noted by two independent observers, was performed in exactly three seconds, being at the rate of 63 knots an hour—a speed that will be allowed to far surpass any speed ever attained by any water-borne object before. The model, owing to the water space being limited, was driven into the bank before the rocket was fully discharged, otherwise more than double the distance of 105 yards might have been effected. Several months before I had made some very satisfactory experiments with this model, when it had attained in rough water a computed speed of 40 knots with 3 oz. of powder, so that the result now recorded was not greater than I had anticipated. The motion of both models was from the beginning to the end of their course completely steady, so as to give them more the appearance of sliding over smooth ice than of passing over the surface of water. There was scarcely any water disturbance, though each model had a fixed rudder of thin metal by which they were directed in an absolutely straight line. There was no splash at starting, and at the end of their course the decks were found unwetted, and so evenly was the motion maintained under the propelling force of the rocket that, had it not been for the draught of air, I feel sure that a set of ordinary chessmen set up on their decks might have remained without being displaced during their course.

"As I felt certain it would be asked what would be the effect of using a rocket to drive a model of the ordinary shape, it is as well to state that not long before I made the experiments now brought forward, I endeavored to propel a ship-shaped model weighing 6 lbs with a rocket of the same size and charge as those used for my inclined plane models. Immediately after the firing of the rocket the model was urged forward, and when the speed increased its fore part was lifted out of the water so as to cause the model to fall over, and thus the experiment ended amid smoke and total confusion.

"The first or larger model was 3 ft. 9 in. long and 5¼in. broad, and floated when at rest in 1¼in. of water. The slope of the three parallel inclines was 1 in 18. The second model was likewise of solid fir, was 29¼in. long and 4¼in. broad, and floated when at rest in ¾in. of water. Its three inclines were sloped to 1 in 17. When drawn slowly over the water these models are found to offer a larger resistance than models of the ordinary shape. This is evidently owing to the fact that at low rates of speed they carry a considerable quantity of water before each of the inclines. This they continue until the equilibrium between the horizontal pressure of the inclines forward and the pressure of the water in the contrary direction is destroyed. This action seems to take place suddenly, when the model at once rises in the water and passes over the mass of the hitherto obstructing fluid. No true lifting action of the water seems to take effect on the inclined planes until the water is relatively in full motion against them. Up to this period the water merely exercises a dead pressure against the inclines. When the vessel is fairly lifted, and the water passes freely beneath its bottom, it will continue to override the water, which can no longer be removed in the brief time given for the vessel's passage, and to use this irremovable water as a support or fulcrum of infinite lubricity over which it glides with comparatively small and scarcely increasing resistance.

"On one occasion I used the 7 lb. model with a rocket of the same power as those employed in the experiments detailed, and found that over waves which might have had their intervals equal to one-half the length of the model there was no retardation whatever. The speed recorded and distance run was precisely the same as in a perfectly smooth pond. With other experiments for the same purpose I have always found that waves have not caused any increased obstruction to a model's course."

The facts are summed up by the author as follows:—"I now submit the question to an unprejudiced public, among whom no doubt will be found many who will repeat my experiments with the same results, and by their verification aid me in overcoming those countless difficulties which every inventor has to encounter, when the invention he offers is one that tends to change the foundations of wealth and runs counter to the prejudice and self-interest of large and important bodies of men."—*Engineer.*

## BOOK NOTICES.

MILK ANALYSIS.—A Practical Treatise on the Examination of Milk and its Derivatives, Cream, Butter and Cheese. By J. ALFRED WANKLYN, M. R. C. S. 12mo, $1. New York: D. Van Nostrand. 1874.

We, in New York, have not yet adopted the elaborate means for preventing the adulteration of food which had for a long time been in operation when this book was originally published. When we have, the value of works of the kind may be better appreciated. Meanwhile however, they are of use, not only on account of the practical information they contain, but also as directing public attention to a question of much importance, especially in the towns. The necessity of a supply of good milk is often regarded as merely a matter of convenience, justice or luxury. But it has been amply proved that the health and proper nourishment of children are very seriously affected by any deviation from the standard of purity in the milk supplied to them. Mr. Wanklyn, the author of the little work before us, has for some years devoted special attention to the

subject of milk analysis, both as a scientific investigation and for the information of local bodies as well as of the Government of Great Britain, and he has given us in a condensed form, the teaching of his experiences. Not the least important chapter in his book is that wherein he exposes the failings of the lactometer, upon which it has too long been the custom to rely, for testing the quality of milk. It has long been affirmed that a more untrustworthy device than the lactometer has seldom emanated from science, but we do not remember to have seen its defects so prominently explained by any previous writer. "It confounds together milk which is exceptionally rich with milk which has been largely watered." And Mr. Wanklyn mentions the case of one of the London prisons where the authorities are especially particular about their supply of milk. They allow no milk to enter the prison unless it comes up to the M mark on a certain lactometer. The mark is pitched very high, and the milk purveyor reaches it by skimming the milk. This will be readily understood when the composition of milk is remembered. The density of the fluid depends on the presence of sugar, caseine, and mineral matters. It is lessened by the presence of fat globules. Thus, one trick of the milk trade is actually encouraged by the lactometer. The milk is partially deprived of its cream first. This increases its gravity. It is then dosed with water until it is brought to the nominal standard. This, it appears, cannot well be discovered by an estimation of the cream afterward, for if the process have been properly performed the watered milk, says Mr. Wanklyn, will throw up the fat that is left on it more perfectly than unwatered milk. He therefore is of opinion that one of the first steps necessary to be taken in milk analysis is to abandon the use of the lactometer. Nor does he think that the creamometer is very much more to be trusted. "The only really safe and satisfactory means of examining milk is by means of an analysis of it." This consists in first determining the solids and the water. The fatty matters have next to be ascertained, which, being subtracted from the total amount of milk solids, gives the amount of "solids not fat," a knowledge of which is sufficient to enable a judgment to be come to as to whether or not the sample of milk has been watered.

In the principle of his analysis, Mr. Wanklyn does not pretend to offer anything new, but in the course of his explanation of the whole detail of the proceeding it will be seen that he has reduced it to an exceedingly simple form; and he has put the matter so plainly and explicitly that no one with any experience in laboratory work can fail to follow him successfully. We shall not attempt to outline the nature of that part of his book, which must be read; but it may be well to note a few of the results of his investigations. Samples of good country milk were found to contain an average of 12.45 per cent, of solid matters. But many of the dairies that supply London are within the metropolis; and it was found, from a similar number of samples of rich town-fed milk, the solids rose to 14.07 per cent. Out of fifty-six samples of milk examined in London only fifteen were unwatered or nearly unwatered. It appears, in fact, as the result of about 1,000 analyses that only about ten per cent. of the milk supplied to the British metropolis is genuine. As a fact, however, of more general importance in increasing the value of the analysis, it must be noted that the composition of milk is found to be very constant. Thus, variations in the diet of the cow show themselves rather in the quantity than the quality of the milk, always assuming that the animal is in good health. A comparison of the milk yielded by the poor and ill-fed Bengali cow in India with that from the highly-fed animals in England, showed very little difference between the two. But the amount given by the former was only a small fraction of that yielded by the latter. Mr. Wanklyn does not appear to have much faith in the theories of milk-poisoning, and the production of typhoid fever by the use of so-called infected milk. But his notice of this subject is very brief. It is in the other part of its contents that the chief merits of his book will be found, and as a concise practical contribution upon a subject of much hygienic importance we fully recognize its value.—*N. Y. Times.*

MANUEL D'ANALYSE QUALITATIVE ET QUANTITATIVE AU CHALUMEAU. Par H. CORNWALL. 8vo cloth, $10. Paris: Dunod. For sale by D. Van Nostrand.

This fine octavo of nearly 700 pages, is a translation into French of the excellent American edition of Plattner's Blowpipe Analysis. It will prove serviceable to those students who either from requirement or choice, pursue a technical study by aid of a text-book in a foreign language.

MINERALOGY. By F. RUTLEY, F. G. S. (Murby's Text-books.)

Mr. Rutley's little treatise on mineralogy has the merit of expressing in a clear and simple form the facts that are most wanted to be known by the general student of a science for which a small elementary English book is needed. The descriptions are concise, and the selection of the matter under each mineral generally good. Mr. Rutley, furthermore, gives some fifty pages of preliminary matter, which, though not always put in the most intelligible form, yet embodies a considerable amount of useful technical teaching in regard to the physical properties of minerals. Mr. Rutley even enters, and very rightly does so, on the subject of optical characters. But in these pages, as in the page on thermo-electricity, the author does not seem to have carefully revised what he wrote, or he would not have followed other authors in speaking of boracite as a uniaxal crystal, and would hardly have classed the dispersion of light by a diamond with the play of color exhibited by an opal. Nor is an optic axis correctly described as the only direction by looking along which the doubly-refracted images of a spot can be got to coincide, as Mr. Rutley will see if he looks at the spot through two opposite faces of the hexagonal prism of a calcite crystal. He ingeniously endeavors to indicate the nature of the faces of his crytals by a sort of heraldic hatching and marking. The use of small letters always indicating the character of the faces, as in Des Cloizeaux and other French treatises, might have done this usefully; Mr. Rutley's puzzling figures will probably only serve to scare away the English student, who needs every allurement to the study of the neglected science of crystallography—a science neglected merely because the rudiments of

geometry and trigonometry are not made a necessary part of every scientific student's education. And it is a significant circumstance in connection with this neglect of scientific crystallography, that the geometrical methods and simple notation introduced forty years ago by our distinguished fellow-countryman, the first living crystallographer, Prof. Miller, are, we believe, untaught in any single lecture-room in London.

THE MARTYRS OF SCIENCE. By SIR DAVID BREWSTER. New Edition, with portraits. London: Chatto & Windus. 1874.

This is a re-issue of an old and excellent book, consisting of the biographies of Galileo, Tycho Brahe and Kepler, three of the great lights of astronomical science. The tale of their lives is well and impartially told. They were troubled beyond what one would naturally expect to find in the case of men devoted to what apparently ought to be the quietest and most contemplative of pursuits; but after a careful perusal of their stories, one cannot help thinking that, not even excepting Galileo, they brought a great deal of their life-sorrows upon their own heads. A little bending to the inevitable, a better command of temper, and more attention to time and circumstance, would have enabled all of them to turn the flank of their perplexities without detriment to the truths which had been given them to proclaim.—*Iron.*

TREATISE ON PRACTICAL SOLID OR DESCRIPTIVE GEOMETRY; EMBRACING ORTHOGRAPHIC PROJECTION AND PERSPECTIVE OR RADIAL PROJECTION. By W. TIMBRELL PIERCE, architect, late Lecturer on Geometrical Drawing at King's College and Harrow School. With eighty-eight Plates of Original Drawings. London: Longman, Green & Co.

Mr. Pierce informs us in his preface that he has been induced to write this work from the want felt of a good English text book on the subject, and we agree with him that in this respect our technical literature has been behind that of France and Germany. The want just referred to Mr. Pierce appears to have well filled, and his treatise contains an extensive series of problems clearly treated and illustrated by diagrams well drawn and engraved to a large scale. The letter-press descriptions, too, are sufficiently full to enable a student to follow the problems without further explanation from a teacher, a point of importance to many.

MANUAL FOR RAILROAD ENGINEERS AND ENGINEERING STUDENTS. By Prof. GEO. L. VOSE, C. E. Boston: Lee & Shepard. Price $12.50. For sale by D. Van Nostrand.

This is the second edition of this excellent work. The two former volumes now appear in one, and at a price considerably below that of the old edition.

The book is absolutely indispensable to the railway engineer, or to the engineering student who aspires to a knowledge of the practical in railway matters.

From the reconnoissances to the management of the running work, everything pertaining to this branch of Civil Engineering is fully and successfully treated.

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The advertisement to be found in another page specifies the topics in their order of treatment. At another time we will speak at greater length of the merits which fit this work for students.

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## MISCELLANEOUS.

TIN glaze, for pottery, originated in the East. Staniferous glazes are found with Egyptian mummies, on the splendid productions of the Persian potter, whose date we can only guess at, and in tiles from the Moorish palaces of Southern Spain. It is, then, to be supposed that this secret lay long dormant among Oriental races, and was revived and communicated to European nations, with so many other half-lost arts by the Arabs, and Moors who conquered Spain. Tiles with tin glazes are found in the Alhambra, with a date corresponding to 1300 A. D., and there is no doubt that the Moorish potteries were established in this and the following centuries in Spain, in Portugal, and in Sicily, and wherever else the Moors had made their settlements. The Moorish potters made a very beautiful ware, known to collectors as Hispano-Moresque, and easily recognizable by the peculiar metallic lustre on its surface. This ware was largely exported from Spain to Italy, insomuch that the finest pieces are to this day found in that country, and not in Spain; and in time the Italians began to set up potteries of their own, and to imitate the Moorish ware. They called their imitations Majolica, or Maiolica—the ancient Italian name of Majorca—either because the Moorish pottery was made there or thence brought, or because the Italians fancied that it was. At first the Italian potters could not compass either the lustre of the Moorish ware or the rich, enamel-like glaze of these foreign potters, and their first works were lead-glazed, and are known to collectors as half Majolica—"Mezza Majolica;" but towards the end of the fifteenth century they began to imitate the lustred wares. At last they got hold of the great tin secret, and their pottery soon surpassed the Hispano-Moresque wares in beauty. In the Moors' own specialty of lustred wares they were excelled by the Italians, and at the town of Gubbio a mode of imparting a lustre of a red color of surpassing beauty was invented—a secret that was never disseminated, and soon lost; and the rare ruby-lustred plates of Gubbio are now among the greatest treasures of the art collector.

A RELIC OF THE MOUND BUILDERS.—Dr. H. H. Hill, one of the most enthusiastic and successful collectors of American relics, on a late excursion to Ironton, discovered the great sandstone anvil of these wonderful people. It was found about two miles above Ironton, on the farm of Mr. Luke Lelly. It is composed of very sharp grit, contains over one hundred depressions, weighs about five hundred pounds, and measures eight feet eight inches at its greatest circumference. It will be placed in the rooms of the Cincinnati Society of Natural History, to which society the doctor proposes to present it.—*Iron Age.*